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SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR.
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosenergoizdat	State Power Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LEIIZhT	Leningrad Power Inst. of Railroad Engineering
LET	Leningrad Elec. Engr. School
LETI	Leningrad Electrotechnical Inst.
LETIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MEP	Ministry of Electrical Industry
MES	Ministry of Electrical Power Plants
MESEP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTI	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.-Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOE	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIEL	Central Scientific Research Elec. Engr. Lab.
TsNIEL-MES	Central Scientific Research Elec. Engr. Lab.—Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIESKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Meteorology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZEI	All-Union Power Correspondence Inst.

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us. — Publisher.

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TETRAHETEROPOLYACIDS WITH A CENTRAL PHOSPHORUS ATOM. VII

A. I. Kokorin

We use the term tetraheteropolyacid to describe those heteropolyacids containing the acid residues of four simple acids in the complex anion. In the same way we shall refer to heteropolyacids with the residues of two and three acids as di- and triheteropolyacids.*

We have found no data in the literature on tetraheteropolyacids, apart from observations that they can evidently be prepared. The experience which we have gained in the synthesis of triheteropolyacids in general, and of triheteropolyacids with different ratios of molybdenum and tungsten in particular [1], has enabled us to set about the realization of this task. In synthesizing the tetraheteropolyacids we had in mind the preparation of strictly defined limiting compounds of a saturated series with a central phosphorus atom, corresponding to the following formulas

$$H_7[P(Mo_2O_7)_4W_2O_7V_2O_6] \qquad (1)$$

$$H_7[P(Mo_2O_7)_3(W_2O_7)_2V_2O_6] \qquad (2)$$

$$H_7[P(Mo_2O_7)_2(W_2O_7)_3V_2O_6] \qquad (3)$$

$$H_7[PMo_2O_7(W_2O_7)_4V_2O_6] \qquad (4)$$

This aim could be achieved by starting from stoichiometric amounts of the materials being used (except in the case of vanadium, whose salt was taken in 2-fold excess), an essential requirement being that the reaction should take place completely (or uniformly). A second necessary condition is the preliminary conversion of the normal tungstate and molybdate to the metacompounds. This conversion was carried out in the same way as in the synthesis of phosphomolybdotungstic acids [1].

Description of the synthesis. The quantities of the starting materials taken for the synthesis of the tetraheteropolyacids, and the quantities of hydrochloric acid (1 : 1) used for the conversion of the tungstate and molybdate to the metacompounds for 5 g disodium hydrogen phosphate ($Na_2HPO_4 \cdot 12H_2O$) are given in Table 1.

TABLE 1

Quantities of Starting Materials

Tetraheteroacid formula	$Na_2WO_4 \cdot 2H_2O$ (in g)	6 N HCl (in ml)	$Na_2MoO_4 \cdot 2H_2O$ (in g)	6 N HCl (in ml)	$NaVO_3$ (in g)
(1)	9.2	6.9	27.0	27.5	6.8
(2)	18.4	13.8	20.25	20.65	6.8
(3)	27.5	20.7	13.5	13.8	6.8
(4)	36.85	27.65	6.75	6.9	6.8

---

* We have previously referred to these compounds as heterodi- and heterotriacids.

The tungstate samples were dissolved in 5 times their weight of water, the molybdate samples in 3 times their weight of water. The tungstate and molybdate were converted to the metacompounds by the addition of hydrochloric acid. The hot sodium metamolybdate solution was added to the hot metatungstate solution formed. In this process the solution acquired a deep red color. The mixtures of the stirring materials were boiled for 2 hours in a conical flask of 300 ml capacity fitted with ground-glass reflux condenser. The preparation of the etherate and further operations were carried out as in the synthesis of phosphomolybdotungstic triheteropolyacids. The etherate of the tetraheteropolyacid begins to form at H_2SO_4 concentrations between 1.8 and 2.5 N. Further addition of sulfuric acid was carried out in small portions, with cooling of the mixture in a separating funnel. When a turbidity was produced during the addition of the acid, further addition was stopped until the solution had become clear. Formation of etherate stopped at H_2SO_4 concentrations between 6.2 and 6.7 N for the tetra-acids (1) and (2), and between 8 and 8.5 N for the tetraacids (3) and (4). The crystallization of the etherate after its separation and decomposition with water at slightly raised temperature was carried out isothermally in air. Bright red crystals were obtained, with well-defined faces, of octahedral form or in the form of octahedra with cut-off corners.

Analysis. The water of crystallization was determined by drying at 130-140°. Each tetraheteropolyacid was synthesized twice, and the water determined in two samples of each of the products obtained. For acid (1) the water content varied between 30.3 and 30.7 molecules, while for acids (2), (3) and (4) it varied between 28.8 and 32 molecules.

The phosphorus was determined in the form of $Mg_2P_2O_7$ by the classical method after decomposition of the tetraheteropolyacids by boiling with caustic soda solution and precipitation with magnesia mixture in the presence of sodium potassium tartrate. Four analyses were carried out for each tetraheteropolyacid. The deviation from the mean value in the separate determinations did not exceed 0.1%. The phosphorus content for acid (1) equalled 1.6%, for acids (2) and (3) – 1.5% and for acid (4) – 1.3% of the weight of the anhydrous specimen.

Molybdenum was determined in the solution after the precipitation of the phosphorus. The molybdenum was first precipitated in the form of its sulfide with hydrogen sulfide in the presence of tartaric acid [2]. The sulfide was dissolved in a warm solution of ammonia (1: 1) containing a small quantity of perhydrol and the molybdenum precipitated in the form of lead molybdate [3]. The means values for the molybdenum content were 39% for acid (1), 28% for acid (2), 17% for acid (3) and 8% for acid (4).

The tungsten was determined in the form of WO_3 from a separate sample after removal of the phosphorus with magnesia mixture. Since, however, the tungstic acid precipitate contained perceptible amounts of adsorbed molybdenum, it was dissolved in hot 2N caustic soda solution and the molybdenum precipitated with hydrogen sulfide after acidification and addition of tartaric acid. The tungsten in the filtrate was precipitated a second time in the form of tungstic acid. The mean values for the tungsten content from two analyses of each of the tetraheteropolyacids synthesized were: in (1) – 18.5%, in (2) – 35%, in (3) – 47% and in (4) – 60%.

The vanadium was determined in a separate sample after decomposition of the tetraheteropolyacid by boiling with 2N caustic soda solution, using the phenylanthranilate method. Its mean concentration from three determinations on each tetraacid sample amounted to 5.4% in (1), 4.9% in (2), 4.5% in (3) and 4.1% in (4), relative to the weight of anhydrous sample.

The analytical results for some samples are given in Table 2.

TABLE 2

Results for the Analysis of Phosphomolybdotungstovanadic Acids

Acid	P		Mo		W		V		Ratio
	mg	mg-at	mg	mg-at	mg	mg-at	mg	mg-at	
(1)	16.0	0.5	380.0	4.0	182.0	1.0	55.0	1.1	1 : 8 : 2 : 2.2
(2)	14.0	0.5	314.0	3.3	340.0	1.8	49.0	1.0	1 : 6.6 : 3.6 : 2
(3)	16.0	0.5	166.0	1.7	474.0	2.6	45.0	0.9	1 : 3.4 : 5.2 : 1.8
(4)	12.0	0.4	73.0	0.8	579.0	3.1	41.0	0.8	1 : 2 : 7.7 : 2.0

The ratios found are close to the theoretical values. The marked discrepancy in the case of acid (3) may be explained by the considerable difficulty in determining phosphorus, molybdenum and tungsten in the presence of one another and vanadium. The aqueous and ether layers above the etherate after its separation were analyzed in all cases for their phosphorus, molybdenum, tungsten and vanadium contents. From this it was shown that these elements are present in these solutions in extremely small amounts. Consequently, the starting materials used have reacted completely to form the tetraheteroacid etherates.

Properties. All the tetraacids synthesized are orange-colored materials which crystallize well in the form of regular octahedra (Figure 1) which occasionally have cut-off corners.

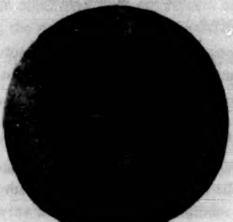

Fig. 1. Crystals of $H_7[P(Mo_2O_7)_3(W_2O_7)_2V_2O_6] \cdot nH_2O$.

Their crystallization, as a rule, takes place with a large and comparatively constant number of water molecules. The total water content in certain specimens amounts to 34-36 molecules. Of these, 31-32 molecules are removed by heating to 160°. Further heating at 260° for 5 hours produces no change in weight. The last 3-4 water molecules are removed only on prolonged heating to a temperature of 460°. These are evidently molecules of water of constitution, on removal of which the oxides of the components of the tetraacids are formed.

For the determination of the temperature at which the tetraacids dissolve in their water of crystallization, specimens with closely similar water contents were chosen. The melting points of the hydrates with thirty water molecules present are given below:

$H_7[P(Mo_2O_7)_4W_2O_7V_2O_6] \cdot 30H_2O$ — 47.0°,
$H_7[P(Mo_2O_7)_3(W_2O_7)_2V_2O_6] \cdot 30H_2O$ — 49.0°,
$H_7[P(Mo_2O_7)_2(W_2O_7)_3V_2O_6] \cdot 31H_2O$ — 50.0°,
$H_7[PMo_2O_7(W_2O_7)_4V_2O_6] \cdot 30H_2O$ — 52.0°.

It can be seen from the data given that the melting points of all four compounds are comparatively close together, although a slight increase is observed with increasing tungsten content.

The potentiometric titration of the tetraheteropolyacid solutions with caustic potash and the measurement of the electrical conductivity were carried out in exactly the same way as described earlier [1]: 20 ml of water was added to 20 ml of 0.02 M tetraacid solution and the resultant solution titrated with 0.2 N KOH solution.

The tetraheteropolyacids are very stable toward alkalies. After the first jump in the titration (neutralization of the salt-forming hydrogen ions) a constant potential is established only when the solutions are subjected to prolonged boiling after the addition of each portion of alkali. Figure 2 shows the potentiometric titration curves of two of the acids – (1) and (4).

The molar conductivity μ was measured for the tetraheteropolyacids (1) and (4) and for their potassium salts. The results of the measurements are given in Table 3.

0.02 M solutions of the acids and 0.05 N solutions of their salts were prepared to study the behavior of the tetraheteroacids toward cations, reducing agents and organic substances.

All the tetraacids give bright yellow precipitates with cesium chloride, and with thallium nitrate form voluminous orange precipitates, insoluble in the cold in dilute (1 : 1) mineral acids. The precipitates formed with thorium nitrate (yellow colored), with zirconium nitrate (light-orange), and also with silver nitrate and mercurous oxide (light-violet) dissolve in the cold in HNO_3 (1 : 1).

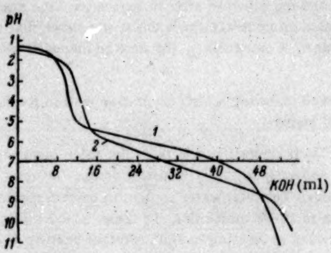

Fig. 2. Titration curves of solutions of $H_7[P(Mo_2O_7)_4W_2O_7V_2O_6]$ (1) and $H_7[PMo_2O_7(W_2O_7)_4V_2O_6]$ (2).

The tetraacids are precipitated by urotropin, cupferron, 8-hydroxyquinoline, pyrogallol, pyramidon, dimethylglyoxime and benzidine in the form of precipitates with colors from yellow to orange-brown, which are soluble with difficulty in dilute (1: 1) mineral acids on heating. The precipitates formed with urotropin, cupferron, and pyramidone dissolve in excess of these reagents.

All the phosphorus tetraheteropolyacids obtained are reduced by salts of Fe^{++}, Sn^{++}, Ti^{4+}, Sb^{3+}, and by diphenylcarbazide, diphenylamine, hydroquinone and thiourea.

The tetraacid crystals are readily soluble in butyl and isobutyl alcohols, in glacial acetic acid and in acetone.

DISCUSSION OF RESULTS

The work has established the optimum conditions for the synthesis of tetraheteropolyacids with central phosphorus atoms containing as addenda tungsten, molybdenum and vanadium simultaneously in varying amounts. Four tetraheteroacids have been isolated in the free state.

The synthesis of tetraheteroacids of strictly definite composition has become possible thanks to the discovery by us of the general condition that for the isolation of a series of complex heteropolyacids in the free state it is necessary first of all to convert the normal tungstate into metatungstic acid.

TABLE 3

Molar (μ) and Equivalent (λ) Conductivities of Tetraheteropolyacids

Acid	Acid				Salt			
	μ_{256}	μ_{512}	μ_{1024}	λ_{1024}	μ_{256}	μ_{512}	μ_{1024}	λ_{1024}
(1)	1498	1587	1727	348	502	560	620	124
(4)	1770	1827	1896	316	695	742	824	137

The results of the analysis of the acids synthesized give grounds for ascribing to them the following formulas:

$$H_7[P(Mo_2O_7)_4W_2O_7V_2O_6] \cdot n\,H_2O,\ H_7[P(Mo_2O_7)_3(W_2O_7)_2V_2O_6] \cdot nH_2O,$$
$$H_7[P(Mo_2O_7)_2(W_2O_7)_3V_2O_6] \cdot nH_2O,\ H_7[PMo_2O_7(W_2O_7)_4V_2O_6] \cdot nH_2O.$$

It should be noted that this group of heteropolyacids crystallizes as a rule with a very large and relatively constant number of water molecules (n = 29-32).

Potentiometric titration of the tetraacids obtained, measurement of the molecular conductivity, and calculation of the equivalent conductivity of solutions of acids (1) and (4) and their potassium salts show that the first tetraacid has five hydrogen ions replaceable by potassium, while the remaining acids are hexabasic. The compounds synthesized must be given the formulas:

$$H_5H_2[P(Mo_2O_7)_4W_2O_7V_2O_6],\ H_6H[P(Mo_2O_7)_3(W_2O_7)_2V_2O_6],\ H_6H[P(Mo_2O_7)_2(W_2O_7)_3V_2O_6],$$
$$H_6H[PMo_2O_7(W_2O_7)_4V_2O_6],$$

where the hydrogen ions which form salts when the acids are neutralized with KOH solution are given first.

The tetraheteroacids synthesized give characteristic precipitates with a number of cations and organic compounds. They exhibit a comparatively high oxidizing power oxidation potential approximately 0.77v).

The melting points of their crystal hydrates do not exceed 52°. The tetraheteroacids studied dissolve readily in a number of organic solvents.

When generalizing from the experimental material obtained by us on the study of the 17 saturated triheteroacids and the 4 tetraheteroacids of the limiting series which we have synthesized and described earlier [4], it is particularly necessary to pay attention to the following considerations.

The experimental study carried out by us of the optimum conditions for the synthesis of tri- and tetraheteroacids by the etherate method has shown that the deciding factors for obtaining them in the free state are: 1) the stoichiometric ratio of the starting materials, 2) a strictly defined initial acidity for the medium, 3) suitable temperature conditions, 4) the acidity during the heteroacid etherate formation, 5) the crystallization conditions, 6) the nature of the starting materials.

The difficulty of attachment of addenda to the central atom increases with increase in the ionic radius of the central atoms (in the order P, Si, As, Ge). For one and the same central atom, molybdenum is attached fairly easily. Vanadium enters the tri- and tetraheteroacids only in the form of one group – V_2O_6. In the synthesis of the triacids, tungsten is the most difficult to introduce. The nature of the anion of the starting component entering the heteropolyanions has considerable influence on the successful synthesis of the triheteroacids. The metavanadate ion (VO_3^-) is introduced more readily than the orthovanadate (VO_3^{3-}). The nature of the tungstate ion has a particularly powerful influence, and this is not only due to the fact that tungstic acid may be precipitated in acid medium. Using normal tungstate, it was possible to synthesize only phosphotungstovanadic acid (using a slight excess of phosphoric acid); the other triacids could not be synthesized in this way. Preliminary conversion of the normal tungstate to the paratungstate does not help. Countless experiments have established that to carry out the synthesis successfully, particularly when attaching groups to a central silicon atom, it is necessary, first of all, to convert the normal tungstate used into the metatungstate. In the synthesis of tri- and tetraheteroacids with different but strictly defined ratios of tungsten and molybdenum, taking the above-mentioned considerations into account, the normal tungstate and molybdate must be converted beforehand into the meta-compounds. This conversion has been carried out under definite conditions by the action of the calculated quantities of hydrochloric acid based on the equations

$$\begin{array}{c} 9Na_2WO_4+18HCl=9WO_3+18NaCl+9H_2O \\ 3Na_2WO_4+9WO_3+3H_2O=Na_8H_4[H_2(W_2O_7)_6)] \\ \hline 12Na_2WO_4+18HCl=Na_6H_4[H_2(W_2O_7)_6]+18NaCl+6H_2O \end{array}$$

On the basis of a large amount of experimental material obtained while working out methods for the synthesis of tri- and tetraheteropolyacids, we have grounds for concluding that the addenda have the same composition and structure as in the metatungstates (metamolybdates), i.e., they contain the groups $Me_2O_7^{--}$.

Careful quantitative determination of the vanadium content in the tri- and tetraheteroacids has shown that the ratio of phosphorus (or silicon) to vanadium in all the compounds synthesized is equal to 1 : 2. The fact that only monosubstituted complexes (one coordination position substituted) are obtained indicates that their coordination number equals six and does not agree with Keggin's theory, according to which the formula of the addendum should be $[Me_3O_{10}]_4$. In the latter case, when saturated heteropolyacids of the limiting series, containing one V_2O_6 group, are prepared, we should have the ratio Mo(W) : V = 9 : 2, whereas we find that this ratio is always equal to 10 : 2.

Studies have shown that the removal of the heteropolyacid water depends on the nature of the central atom and also on the composition of the addenda. In all the compounds studied the water molecules occupy a different position, and removal of the water takes place stepwise. The last 3.5–4 water molecules are removed only at high temperatures (460-480°). We are inclined to believe that these water molecules are formed by the decomposition of the heteropolyacids at the high temperatures.

The results of potentiometric titration of the heteropolyacids studied by us with caustic potash solutions show the presence of two titration jumps. The only exceptions are phospho- and silicotungstovanadic acids with which the second titration jump is not detected. The first titration jump corresponds to the neutralization of the acidic hydrogen ions, which give the basicity of the heteropolyacids, shown by them in neutralization with strong alkalies. The second potential jump corresponds to the complete decomposition of the heteropolyanion, i.e., to the formation of the simple salts of the acids making up the acid complex.

The sharpness of the first titration jump depends on two factors: 1) the degree of dissociation of the heteropolyacid as an acid, on the one hand, and 2) the stability of the heteropolyanion towards alkalies, on the ether. When a heteropolyanion unstable towards alkalis is present, and when the dissociation of the heteropolyacid is insufficient, reaction between the alkali and the heteropolyanion takes place at the same time as the neutralization process. One process is then superimposed on the other, the determination of the basicity from the first titration jump is made difficult, and inconsistent results are obtained. The alkali reacting with the heteropolyanion has almost no effect on the magnitude of the pH, and the first part of the curve corresponding to the first titration jump acquires a considerable slope – is "eroded." This, in our opinion, explains the contradictory results obtained in the determination of the basicity of phosphomolybdic acid. The heteropolyanion of phosphomolybdovanadic acid is more stable, and the first titration jump is well-defined; it is less well-defined, however, than in the case of triacids with a central silicon atom and the tetraheteroacids of phosphorus. The stability of the heteropolyanion towards alkalies also determines the nature of the medium (acidic or alkaline) in which the intermediate region lies. The second titration jump also depends on the character of this intermediate region.

The second titration jump is clearly defined if the heteropolyanion is unstable, and, on the contrary, with a stable heteropolyanion this jump becomes indistinct or is completely absent.

The results of potentiometric titration with alkali, the measurement of the molar conductivity of solutions of the tri- and tetraheteroacids and their potassium salts at high dilutions, together with the calculation of the equivalent conductivity and the measurement of the pH values at different dilutions, make it possible to reach the following conclusions concerning the number of salt-forming hydrogen ions.

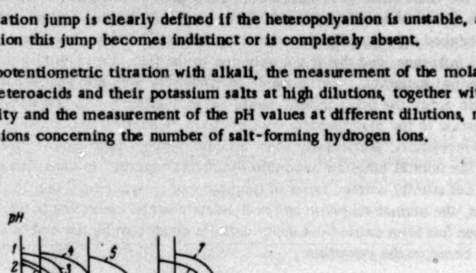

Fig. 3. Titration curves of heteropolyacid solutions.
1) phosphomolybdic, 2) silicomolybdotungstic, 3) silicotungstovanadic, 4) phosphotungstovanadic, 5) phosphomolybdotungstic, 6) phosphomolybdotungstovanadic, 7) phosphomolybdovanadic.

The heteropolyacids described fall into three groups according to the number of salt-forming hydrogen ions. The first group consists of the silicomolybdotungstic triacids, which have four salt-forming hydrogen ions in solution. The second group, with five salt-forming hydrogen ions, contains all the phosphomolybdotungstic triacids, the tetraacid (1), silicomolybdovanadic acid and the triacids containing germanium and vanadium. The remaining phosphorus tetraheteroacids, together with silicotungstovanadic and phosphotungstovanadic acids, have six hydrogen ions in solution capable of forming salts in the titration with caustic potash.

Analysis of the results obtained shows that the basicity of the tri- and tetraheteroacids depends not only on the nature of the central atoms, but also to a considerable extent on the nature and composition of the heteropolyanions. In our opinion, the succession of contradictory data obtained earlier in determinations of the basicity of certain diheteropolyacids is explained primarily by failure to take the above-mentioned fact into consideration.

As shown by the titration curves for a number of heteropolyacids, given for comparison in Figure 3, the first and second titration jumps and the intermediate region depend on the nature of the central atoms and also, to no less an extent, on the addenda.

The least well-defined (eroded) first titration jump is given by phosphomolybdic acid since decomposition of the heteropolyanion begins. The first titration jump is more clearly defined for phosphomolybdotungstic acid and the most clearly defined first jump is that given by silicomolybdotungstic acid III; silico- and phosphotungstovanadic acids show no second titration jump. The titration curves of the remaining acids occupy an intermediate position, as far as the sharpness of the first jump is concerned. The central part of the titration curve is highly characteristic. It lies fully in the acid region or fully in the alkaline region, depending on the stability of the heteropolyanion. In the case of certain acids this intermediate region lies in both media.

The tri- and tetraheteroacids studied by us give difficultly soluble precipitates with a number of cations and organic compounds; they show varying oxidizing power; they have varying solubilities in organic solvents. The properties mentioned give grounds for suggesting that they may be used as a source of new analytical reactions.

SUMMARY

1. The optimum conditions have been worked out for the synthesis and isolation in the free state of four tetraheteropolyacids with central phosphorus atoms containing as addenda molybdenum, tungsten and vanadium simultaneously in various proportions.

2. The composition of the new compounds prepared and the number of hydrogen ions in them replaceable by potassium have been determined.

3. Certain physical and chemical properties of the tetraheteropolyacids synthesized have been determined.

4. First generalizations have been made from the study of the tri- and tetraheteropolyacids.

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A STUDY OF THE SYSTEMS OF ZINC PERCHLORATE, LITHIUM HALIDES AND ACETONE BY THE METHODS OF PHYSICOCHEMICAL ANALYSIS

M. S. Barvinok

In the literature it is considered established that in solutions of zinc halides, complex halogeno-zinc compounds of different composition are formed, depending on the conditions (concentration, excess of halide ions, solvent). Thus, for example, the compounds $ZnCl_2 \cdot 2NaCl \cdot 3H_2O$; $ZnBr_2 \cdot NaCl \cdot H_2O$; $ZnBr_2 \cdot 2NaBr \cdot 5H_2O$; $ZnI_2 \cdot NaI \cdot 2H_2O$; $ZnI_2 \cdot 2NaI \cdot 3H_2O$, and also complex zinc halides with other alkali metals, have been isolated in the free state [1].

The existence of several complex halogeno-zinc compounds has been confirmed both in the solid state and in solution: Engel [2], for example, isolated the compounds $2ZnCl_2 \cdot HCl \cdot 2H_2O$ and $ZnCl_2 \cdot HCl \cdot 2H_2O$ in the free state, while I. M. Cheltsov [3] confirmed their presence in solution. The formation of complex chloro-zinc compounds in the solid phase has also been confirmed by D. I. Kuznetsov [4].

The existence of the acids $H[ZnCl_3]$, $H[ZnBr_3]$ and $[HZnI_3]$ in aqueous solution has also been established [5].

The work of Hittorf [6] on the study of the transport numbers of Zn^{++} ions in solutions of zinc chloride and iodide is of great interest in examining the state of zinc ions in halide solutions. He established that the transport numbers of the Zn^{++} ions decrease with increase in concentration and acquire negative values at a definite concentration. At this stage the zinc ions move toward the anode as complex halogeno-zinc anions. Hittorf discovered that in solutions of zinc chloride a more pronounced decrease in transport numbers took place with increase in concentration than in solutions of zinc iodide. This led to the assumption that the tendency to form complex halogeno-zinc compounds in solution decreases from the chlorides to the iodides.

In non-aqueous solutions, according to Hittorf's data, the negative values of the transport numbers of the zinc are of greater absolute magnitude than in aqueous solutions.

Whereas there is no doubt that the formation of complex halogeno-zinc compounds is possible in solutions of zinc halides at fairly high concentrations of the latter or in the presence of an excess of halide ions, opinions on the complex-forming power of zinc ions in the halide ion series have varied with different authors up to the present time.

Doehlem and Fronherz [7], in a study of the absorption spectrum of solutions containing zinc ions in the presence of excess halide ions, came to the conclusion that the zinc ions form complexes more readily with iodide ions than with chloride ions. Egan and Partington came to a similar conclusion on the basis of E.M.F. measurements and the calculation of the activities of the electrolytes concerned [8]. Sillen [9] has studied complex formation in zinc halide solutions by the method of potentiometric titration. On the basis of his measurements he came to the conclusion that chloride ions form complexes with zinc ions more readily than iodide ions. Other authors have reached the same conclusion from studies of complex formation in zinc halide solutions [10, 11]. The question of the relation between the stability of halogeno-zinc compounds and the nature of the halide ion is thus a matter for discussion.

We have studied two sections in the diagonal plane of the following systems by the method of physicochemical analysis: $Zn(ClO_4)_2 - Li_2Cl_2 - (H_2O) -$ acetone, $Zn(ClO_4)_2 - Li_2Br_2 - (H_2O) -$ acetone, $Zn(ClO_4)_2 - Li_2I_2 - (H_2O) -$ acetone. The method for measuring the electrical conductivity, viscosity and density of the solutions has been described by us earlier [12]. The systems mentioned, consisting of two salts without a common ion and a solvent, in which a double exchange reaction is possible, belong to the class of quaternary reciprocal systems. Geometrical representation of the equilibria in each of these systems may be achieved using a rectilinear pyramid with a square base in the corners of which the salts $Zn(ClO_4)_2$, $ZnHal_2$, Li_2Hal_2, $(LiClO_4)_2$, are placed and an apex at which the solvent is placed (Hal = Cl^-, Br^-, I^-). The amount of water in these systems is determined by its concentration in the crystal hydrate $Zn(ClO_4)_2 \cdot 6H_2O$.

EXPERIMENTAL

The zinc perchlorate $Zn(ClO_4)_2 \cdot 6H_2O$ was prepared from zinc carbonate (analytically pure) and perchloric acid (analytically pure) as described in the literature [1]. The $Zn(ClO_4)_2 \cdot 6H_2O$ was recrystallized twice before the preparation of the solutions. The samples of lithium chloride, lithium bromide and lithium iodide were prepared as described earlier [12]. The acetone (analytically pure) was dried with calcium chloride and distilled twice. It was tested as described in the literature [13]. The concentration of the solutions was expressed in molar percentages. The quantity of solvent necessary for the preparation of the solution was calculated by volume, starting from its density at room temperature while the solution was being prepared. The mixtures of solutions were prepared by volume, starting from their densities at the temperature at which the solution volume was measured. The volume of each solution prepared was not less than 300 ml. The volume of the mixture of solutions was 50 ml on the average and was measured using a buret graduated in 0.1 ml.

The properties of the system which were studied were the electrical conductivity, the viscosity and the density. The density of the solutions was used by us for the calculation of their viscosity. Correction of the electrical conductivity for viscosity brought about no essential change in the path of the curves, so that we give here only the electrical conductivity – composition diagrams.

The system $Zn(ClO_4)_2 - Li_2Cl_2 - (H_2O)$ – acetone (total salts 0.18 mole %, H_2O 1.08 mole %, acetone 98.74 mole %). The results of the measurement of the electrical conductivity (κ – electrical conductivity in $ohm^{-1} \cdot cm^{-1}$) of the given system as the composition is varied are given in Figure 1, from which it can be seen that each of the κ – composition curves consists of two branches. The point where they intersect corresponds to a ratio of $Zn(ClO_4)_2$ to Li_2Cl_2 of 2 : 3, which indicates the formation in the system of the compound $ZnCl_2 \cdot LiCl$. The formation of this compound may be represented by the following equation

$$2Zn(ClO_4)_2 + 3Li_2Cl_2 = 2(ZnCl_2 \cdot LiCl) + 4LiClO_4.$$

In order to find out whether the abscissa of the maximum would change in the equilibrium factors, we also studied the relationship between κ and composition for the section with total salt concentration 0.12 mole % at 25 and 40°. As can be seen from Figure 2, the formation of the compound $ZnCl_2 \cdot LiCl$ is confirmed in this case also. The abscissa (composition) on the κ – composition curves remains constant when the temperature is changed from 25 to 40°. Acetone solutions of zinc perchlorate, like acetone solutions of lithium chloride, conduct electricity, the conductivity of the former being greater than that of the latter. Increase in the temperature from 25 to 40° has almost no effect on the electrical conductivity of acetone solutions of zinc perchlorate and lithium chloride, whereas the electrical conductivity of acetone solutions of $ZnCl_2 \cdot LiCl$ increases with increase in temperature.

The system $Zn(ClO_4)_2 - Li_2Br_2 - (H_2O)$ – acetone. The results of the measurements of the electrical conductivity of the sections with total salt concentration 0.24 (H_2O 1.44 mole %, acetone 98.32 mole %) and 0.12 mole %, as the composition of this system is varied, at 25 and 40°, are given in Figures 3 and 4. The data obtained in the study of this system are analogous to those obtained for the system $Zn(ClO_4)_2 - Li_2Cl_2$ – acetone. The formation of the bromo-zinc compound may be represented by the equation

$$2Zn(ClO_4)_2 + 3Li_2Br_2 = 2(ZnBr_2 \cdot LiBr) + 4LiClO_4.$$

The κ – composition curves thus show a particular point corresponding to the formation in the system of the compound $ZnBr_2 \cdot LiBr$, whose abscissa (composition) remains constant (in the region of the stable state) with change in the equilibrium factors (temperature and salt concentration). Acetone solutions of zinc perchlorate and lithium bromide exhibit a lower electrical conductivity than acetone solutions of $ZnBr_2 \cdot LiBr$.

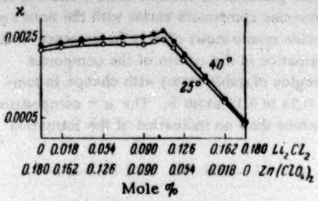

Fig. 1. Electrical conductivity of the system $Zn(ClO_4)_2-Li_2Cl_2-(H_2O)$ – acetone. Total salts 0.18 mole %.

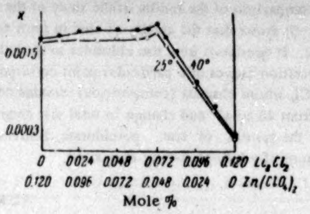

Fig. 2. Electrical conductivity of the system $Zn(ClO_4)_2-Li_2Cl_2-(H_2O)$ – acetone. Total salts 0.12 mole %.

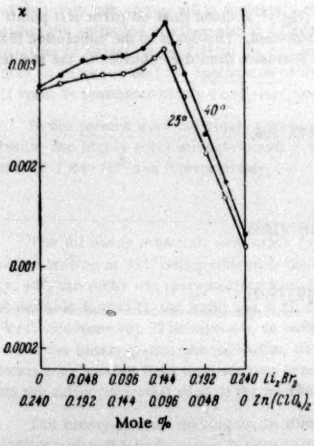

Fig. 3. Electrical conductivity of the system $Zn(ClO_4)_2-Li_2Br_2-(H_2O)$ – acetone. Total salts 0.24 mole %.

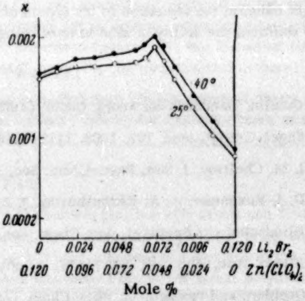

Fig. 4. Electrical conductivity of the system $Zn(ClO_4)_2-Li_2Br_2-(H_2O)$ – acetone. Total salts 0.12 mole %.

The system $Zn(ClO_4)_2-Li_2I_2-(H_2O)$ – acetone (total salts 0.24 mole %, H_2O 1.44 mole %, acetone 98.32 mole %).

The results of the study of this system are given in Figure 5. The κ – composition curves at 25 and 40° show no particular points which might indicate the formation in the system of a definite chemical compound between the zinc perchlorate and the lithium iodide. With increase in the concentration of lithium iodide in the system, the electrical conductivity of the solutions increases.

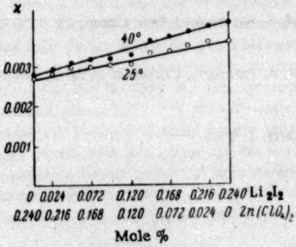

Fig. 5. Electrical conductivity of the system $Zn(ClO_4)_2-Li_2I_2-(H_2O)$ – acetone. Total salts 0.24 mole %.

A comparison of the results of the study of the systems of zinc perchlorate, lithium halides and acetone (Figures 1-5) shows that the ability of zinc to form complex halogeno-zinc compounds varies with the nature of the halide. It decreases from the chlorides to the iodides. The chloride system shows clearly the presence on the κ − composition curves of a particular point corresponding to the formation in the system of the compound $ZnCl_2 \cdot LiCl$, whose abscissa (composition) remains constant (in the region of stable state) with change in temperature from 25 to 40° and change in total salt concentration from 0.24 to 0.12 mole %. The κ − composition curves for the system of zinc perchlorate, lithium iodide and acetone show no indication of the formation in the system of a halogeno-zinc compound.

SUMMARY

1. The systems of zinc perchlorate, lithium halides and acetone have been studied by the method of physicochemical analysis. The properties of the system studied were the electrical conductivity and the viscosity.

2. The κ − composition curves for the system $Zn(ClO_4)_2 - Li_2Cl_2 - (H_2O)$ − acetone show maxima corresponding to the formation in the system of the compound $ZnCl_2 \cdot LiCl$.

3. The κ − composition curves for the system $Zn(ClO_4)_2 - Li_2Br_2 - (H_2O)$ − acetone show maxima corresponding to the formation in the system of the compound $ZnBr_2 \cdot LiBr$.

4. The κ-composition curves for the system $Zn(ClO_4)_2 - Li_2I_2 - (H_2O)$ − acetone show no particular points which might indicate the formation in the system of an iodo-zinc compound. This leads to the conclusion that in acetone solutions the ability of zinc to form halogen compounds decreases from the chlorides to the iodides.

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SEPARATION OF PHASES IN SYSTEMS WITH TWO CHEMICAL COMPOUNDS

I. L. Krupatkin

The study of ternary systems from the separation of phases is widely used for the examination of chemical reaction in their binary predominating systems. Until recently binary reacting systems in which one chemical compound is formed were also studied for the most part by this method. Reacting systems with two chemical compounds have hardly ever been studied from the separation of phases; a few examples of such work are known [1,2]. This is explained not so much by the complexity of these systems as by the fact that in them it often happens that only one compound is accurately reflected on the surface of separation of phases. The second compound is either not reflected at all or else is reflected inaccurately, i.e., the geometrical elements of the surface of separation of phases do not fall on the composition of the compound but on another, often irrational composition. It may be supposed that the application of the method of two solvents to systems with two chemical compounds will make it possible to obtain a complete, accurately reflected picture of the chemical reaction in these systems [3].

In the present work the binary system quinoline–phenol is studied from the separation of phases in two solvents: the highly polar solvent – water – and the non-polar solvent – sulfur; the dipole moments of the solvents are $1.84 \cdot 10^{18}$ and 0, respectively.

EXPERIMENTAL

The following materials were taken for the work: the quinoline was purified with alkali and distilled, the fraction boiling at 237° being collected; the phenol was distilled, the fraction boiling at 181° being collected, m.p. 42°; the sulfur was recrystallized from benzene, had m.p. 117° and consisted of a mixture of the monoclinic and rhombic forms [4]; the water was distilled twice. The work was carried out by the visual polythermal method of V. F. Alekseev [5]. The mixtures, in sealed glass ampoules, were placed in an oil-filled thermostat. In the study of the binary system phenol–sulfur, the crystallization was studied in the same ampoules. The ternary systems were studied from their sections across the temperature-concentration prisms. The sections were taken from the sulfur (or water) edge to the face of the binary system quinoline–phenol.

The binary systems making up the three-component systems studied have the following properties. The quinoline–phenol (Q–P) system has been studied from the melting points [6]. In this system two chemical compounds were detected; one of them melts congruently at 7.2°, contains 53 % phenol and 47% quinoline (molecular ratio 2 : 1); the other compound melts congruently at 22.4°, contains 32.5% phenol and 67.5% quinoline (molecular ratio 2 : 3). The quinoline–sulfur system has been studied from the melting points [7]. This system possessed a curve for a metastable equilibrium between the liquid phases with an upper critical point situated at a temperature of 102° and 69.77% sulfur. In the present work this system had the form of a homogeneous system since the study of the ternary systems was carried out at temperatures above 102°. The phenol–water system has been studied from the melting points and the separation of phases [8]. This system shows a curve for a stable separation of phases with an upper critical point (66°, 34 % phenol). In this work this system had the form of a homogeneous system for the same reason as given previously. The quinoline–water system has been studied from the separation of phases [9]. It has been established that with increase in the temperature, the solubility of quinoline in water increases, while the solubility of water in quinoline decreases. The phenol–sulfur system is studied in the present work.

The phenol–sulfur system was studied from the melting points and the separation of phases. The numerical data are given in Table 1, and the part of the composition diagram studied is shown in Figure 1. This system was not studied in the sulfur corner because of the low mutual solubility of the liquid phases. Figure 1 shows that in this system a stable separation of phases takes place with an upper critical point in a high position. Monotectic equilibrium is established at 105°. The point F corresponds to 88% phenol. The solubility of sulfur in phenol is almost independent of temperature, so that as the temperature is raised both the curve of the separation of phases (Sep) and the crystallization curve (Cryst) rise steeply.

TABLE 1

Equilibrium in the System Phenol–Sulfur

Phenol concentration (% by weight)	Temperature	
	of crystallization	of separation of phases
80.56	105.0°	145.0°
85.05	—	125.5
87.00	—	117.0
90.17	103.0	—
92.50	98.0	—
95.32	75.0	—

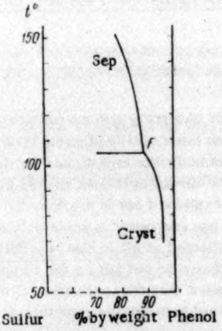

Fig. 1. Equilibrium of solid and liquid phases in the sulfur–phenol system. Sep – separation of phases, Cryst – crystallization.

In the ternary system phenol–quinoline–sulfur, six sections were studied. The numerical data obtained are given in Table 2 and the solubility polythermals themselves are shown in Fig. 2. Increasing polytherm numbering corresponds to increasing quinoline content in the sections. The mutual solubility of the liquid phases in the sulfur corner in sections 1-5 was not studied for the same reason as in the binary system phenol–sulfur. Figure 2 shows that the first three sections differ from the remainder in that their polythermals are situated very close to one another. In all the sections the mutual solubility of the liquid phases shows little dependence on temperature, so that as the temperature is raised all the polythermals rise steeply.

TABLE 2

Polytherms of the System Quinoline–Phenol–Sulfur

Section I 25% quinoline, 75% phenol		Section 2 35% quinoline, 65% phenol		Section 3 47% quinoline, 53% phenol	
sulfur concentration (% by weight)	temperature of separation of phases	sulfur concentration (% by weight)	temperature of separation of phases	sulfur concentration (% by weight)	temperature of separation of phases
10.00	80.0°	13.00	100.0°	10.00	67.0°
15.08	111.0	18.00	120.0	15.00	97.5
20.00	134.0	23.00	140.0	20.00	126.0
				25.10	144.0
Section 4 57% quinoline, 43% phenol		Section 5 67.5% quinoline, 32.5% phenol		Section 6 80% quinoline, 20% phenol	
15.00	90.0	15.00	74.0	20.00	86.0
20.00	111.0	20.21	94.0	30.00	110.5
25.14	129.0	30.16	126.0	40.09	134.0
		35.00	139.0	90.00	137.0
				92.00	110.0
				93.00	90.0

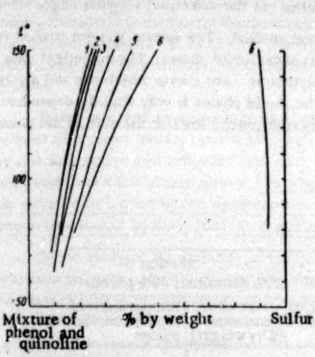

Fig. 2. Solubility polytherms of the ternary system quinoline–phenol–sulfur.

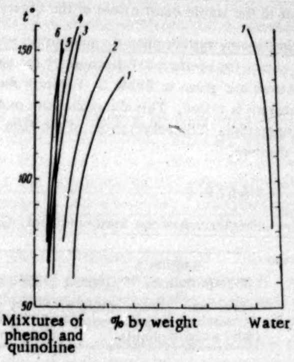

Fig. 3. Solubility polytherms of the ternary system quinoline–phenol–water.

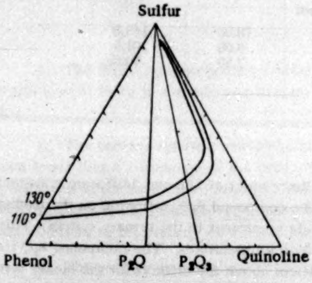

Fig. 4. Solubility isotherms of the ternary system quinoline–phenol–sulfur.

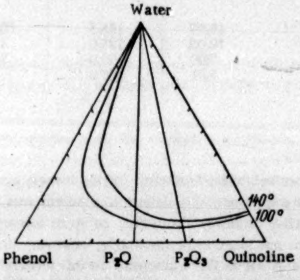

Fig. 5. Solubility isotherms of the ternary system quinoline–phenol–water.

Two isotherms for the separation of phases in the ternary system phenol–quinoline–sulfur at 110 and 130° (Figure 4) were constructed from the polytherms obtained. Figure 4 shows that in the ternary system, at temperatures above the critical for the binary system sulfur–quinoline, the quinoline acts as a homogenizer. The compound P_2Q_3 is not reflected at all on the solubility isotherms of the ternary system. The compound P_2Q is reflected in the form of an anticlinal singular edge slightly raised above the surface of separation of phases. The shape of the polytherms referred to above also confirms the presence of this compound. Similar ternary systems with slightly raised anticlines on the surface of separation of phases have been known earlier [10]. The sulfur–P_2Q section is thus a quasi-binary section. It divides the ternary system studied here into two ternary systems: phenol–P_2Q–sulfur and sulfur–P_2Q–quinoline. In the first of these there is a normal relation between the components of its predominating system, phenol and the compound P_2Q. As a result of this the isotherms of its separation of phases are straight lines. In the second ternary system the separation of phases in the binary system sulfur–P_2Q is homogenized by the quinoline. The linear isotherms of the first system intersect the curves of the second in singular points in the quasi-binary section, forming an anticline. In the ternary system phenol–quinoline–sulfur there takes place a transition from a metastable equilibrium between the liquid phases of the binary system quinoline–sulfur to the stable equilibrium of the binary system phenol–sulfur via the anticlinal singular edge.

In the ternary system phenol–quinoline–water, six sections were studied. The system was not studied in the water corner for sections 2-6 because of the low mutual solubility of the liquid phases. The numerical data for the sections are given in Table 3. Figure 3 shows that all the polytherms are curves which rise steeply as the temperature is raised. This shows that the mutual solubility of the liquid phases is only slightly dependent on the temperature. The polytherms of the fifth section is the furthest displaced towards the side of the phenol–quinoline mixture.

TABLE 3

Polytherms of the System Phenol–Quinoline–Water

Section 1 25% quinoline, 75% phenol		Section 2 35% quinoline, 65% phenol		Section 3 47% quinoline, 53% phenol	
water concentration (% by weight)	temperature of separation of phases	water concentration (% by weight)	temperature of separation of phases	water concentration (% by weight)	temperature of separation of phases
32.10	136.0°	13.00	90.0°	15.00	146.0°
25.10	121.0	18.00	118.0	10.00	112.0
20.00	106.0	27.00	142.5	7.06	86.0
16.50	84.0			6.00	70.5
90.00	157.0				
95.00	136.0				
97.00	90.5				
Section 4 57% quinoline, 43% phenol		Section 5 67.5% quinoline, 32.5% phenol		Section 6 80% quinoline, 20% phenol	
15.00	154.5	10.00	148.0	10.00	148.0
10.00	125.0	7.50	129.5	8.00	101.5
7.00	99.0	5.00	89.0	7.50	70.0
5.21	81.0				

Two solubility isotherms for the ternary system phenol–quinoline–water at 100 and 140° were constructed from the experimentally determined polytherms. Figure 5 shows the compound P_2Q_3 reflected on the isotherms as solubility minima. From this, an upper ternary critical point should be present in the ternary system. This point was not found experimentally, however, since it is situated at high temperatures. The compound P_2Q is not reflected at all on the isotherms. In this ternary system, at temperatures above the critical for the binary system water–phenol, the latter acts as a homogenizer. As a result of salt formation in the binary system phenol–quinoline, when its components react at their functional groups, there is less hydration of the compound P_2Q_3 than of its component substances. This results in a lowering of the solubility of the compound P_2Q_3 in water by comparison with phenol and quinoline and accounts for the formation of solubility minima on the isotherms of separation of phases of the ternary system.

In the ternary system with sulfur, therefore, the compound P_2Q is formed, but the compound P_2Q_3 is not fixed. In the ternary system with water, on the contrary, the compound P_2Q_3 is fixed, but the compound P_2Q is not established. Comparison of the isotherms of both ternary systems reveals the formation of two chemical compounds in the binary system quinoline–phenol. In the same way it is confirmed experimentally that the method of two solvents is a reliable method for studying reaction in binary systems with two chemical compounds.

In the ternary system phenol–quinoline–sulfur, on the one hand, the separation of phases in the binary system sulfur–phenol weakens the interaction between the phenol and the sulfur. In the same way conditions are established for the stabilization of the compound P_2Q, containing a large percentage of phenol. On the other, to a strengthening of the interaction between the sulfur and the quinoline. As a result of this, compound P_2Q_3, which contains a high percentage of quinoline, becomes unstable in the liquid phase of the ternary system. In the ternary system phenol–quinoline–water the opposite conditions are established; the separation of phases in the binary system quinoline–water weakens the interaction between its components. This promotes the stability of the compound P_2Q_3 with high quinoline content. In the binary system phenol–water, above the critical temperature 66°, the separation of phases is homogenized. This strengthens the interaction between the water and the phenol, which renders the compound P_2Q unstable.

In this way the experimental study of the ternary liquid systems shows that all three constituent binary systems of a given ternary system take part simultaneously in the total interaction. They are linked together by this interaction and influence one another, having a mutual influence on one or other of the forms of interrelationship in each binary system. In a liquid ternary system, the constituent binary systems are connected by the coupled influence of one upon another; this influence operates in such a way that a strengthening of the interaction in one of them leads to a weakening of the interaction in the other two constituent binary systems.

In the study of the stability of compounds in the liquid phase of a ternary system, it is also necessary to take into consideration the general character of the processes taking place in the given system as a whole. In the ternary system quinoline–phenol–water the processes of hydration are developed to the greatest extent. This is connected with the presence of the powerfully hydrating functional groups in the phenol and the quinoline and by the presence of water in the system. As a result of this the compound P_2Q_3 is stabilized in the liquid phase of the ternary system by the hydration processes. The absence of the latter in the ternary system phenol–quinoline–sulfur in the non-polar solvent (sulfur) makes this compound unstable. In the ternary system phenol–quinoline–sulfur, the most highly developed processes are the processes of association of the molecules of the components and the dissociation of their associated molecules. Thus, for example, it is known that sulfur exists in the form of associated molecules undergoing dissociation in organic solvents, particularly in amines [11]. As a result, the compound P_2Q is stabilized in the liquid phase of this ternary system by the association processes. The absence of the latter in the ternary system phenol–quinoline–water accounts for the instability of this compound in the system.

SUMMARY

1. The binary system phenol–sulfur has been studied from the melting points and the separation of phases. In this system there is a stable equilibrium between the liquid phases with an upper critical point in a high position.

2. The ternary system phenol–quinoline–sulfur has been studied from the separation of phases. It has been found that a compound of the predominating system phenol (P)–quinoline (Q) with the composition P_2Q is reflected in the form of an anticlinal singular edge on the surface of separation of the phases in the system; the compound of composition P_2Q_3 is not reflected. A transition takes place here from the metastable separation of phases to the stable, via the anticline.

3. The ternary system phenol–quinoline–water has been studied from the separation into phases. From this and the preceding system, the interaction in the binary system phenol–quinoline has been studied by the method of two solvents. It has been found that the compound P_2Q_3 is reflected on the isotherms of separation of phases in the system in the form of solubility minima; the compound P_2Q is not reflected. It has been shown that this system belongs to the group of systems with an upper ternary critical point.

4. It has been shown that the method of two solvents is a reliable method for the study of the interaction in binary homogeneous liquid systems with formation of two chemical compounds.

5. It has been shown that in a ternary liquid system the constituent binary systems are linked to one another by a coupled influence. A strengthening of the interaction in one of them leads to a weakening of the interaction in the remaining two binary systems.

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THE APPLICATION OF THE METHOD OF TWO SOLVENTS TO THE STUDY OF INTERACTION IN LIQUID SYSTEMS

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The method of two solvents [1], from the point of view of its practical application, involves the study of of a binary system from the separation of phases in two solvents, one polar and the other non-polar. This makes possible a penetrating study of the details of chemical interaction in the binary system. On the other hand, the method of two solvents makes it possible to study the interaction between the components of a binary system from the separation of phases even when this is not reflected at all, or is inaccurately reflected, on the surface of separation of phases in a ternary system. The working out of just such an example of the application of the method of two solvents is the aim of the present work.

There are cases in the literature where the formation of a chemical compound in a binary predominating system has been reflected inaccurately by the geometrical elements of the surface of separation of phases of the ternary systems [2]. In such cases the geometrical elements mentioned do not fall on a rational compound composition, but on another, often irrational, composition. Up to the present time, however, no way has been suggested for avoiding such an anomalous reflection. The theoretical basis of the method of two solvents [1] shows that it may be used as a means of avoiding an inaccurate reflection. To confirm this possibility, in the present work the interaction in the binary system benzoic acid–antipyrine was studied from the separation into phases in two solvents: the polar solvent – water – and the non-polar solvent – benzine.

EXPERIMENTAL

The objects of study were the two ternary systems: benzoic acid–antipyrine–water and benzoic acid–antipyrine–benzine. Both systems were studied from the separation into phases by the visual polythermal method of Alekseev [3] in sealed glass ampoules in an oil-filled thermostat. In each ternary system a study was made of the polythermal sections through their temperature-concentration prisms, going from the water (or benzine) edge to the face of the binary predominating system benzoic acid–antipyrine.

The following materials were taken for the work: pharmacopoeia purity antipyrine with m.p. 113°, chemically pure benzoic acid with m.p. 121°, the benzine fraction boiling between 120 and 140°, and twice-distilled water. The advantages and disadvantages of working with benzine instead of individual hydrocarbons have been pointed out earlier [1]. Antipyrine is a powerful monoacidic base, but contains two tertiary amino groups.

The binary systems making up the ternary are characterized by the following data. The benzoic acid–antipyrine system has been studied from the melting points [4]. This showed one chemical compound, melting congruently at a temperature of 66°, containing 39.3% benzoic acid and 60.7% antipyrine (molar ratio 1 : 1). Antipyrine is completely miscible with water. The benzoic acid–water system has been studied from the melting points and the separation of phases [5]. This showed a stable separation of phases with an upper critical point (temperature 116.2°, 34% benzoic acid). The antipyrine–benzine system has been studied from the separation of phases [1]. This shows a stable separation of phases with an upper critical point situated at high temperatures. Benzoic acid is completely soluble in benzine.

In the ternary system benzoic acid–antipyrine–water, seven polythermal sections have been studied. The numerical data obtained are given in Table 1 and the solubility polytherms are shown in Figure 1. Figure 1 shows that all the polytherms have the same form with maxima of mutual solubility of the liquid phases. The latter rise from section 1 to section 5 and fall from section 5 to section 7. The polytherms of section 5 is thus the highest. In all the sections the maxima of the polytherms are displaced towards the water edge. The solubility of water in mixtures of antipyrine and benzoic acid is approximately 3 times greater than the solubility of these mixtures in water. In mixtures coming close to the ends of the polytherms, the mutual solubility of the liquid phases is only very slightly dependent on temperature, so that the curves of separation of the components rise steeply. In mixtures lying in the central regions of the curves, these two factors are strongly dependent, so that the central parts of the polythermals are sloping.

TABLE 1

Polytherms of the System Benzoic Acid—Antipyrine—Water

Section 1 20% BA, 80% An*		Section 2 33% BA, 67% An		Section 3 39.3% BA, 60.7% An		Section 4 48% BA, 52% An	
water (% by weight)	temperature of separation of phases	water (% by weight)	temperature of separation of phases	water (% by weight)	temperature of separation of phases	water (% by weight)	temperature of separation of phases
40.00	55.0°	21.50	75.0°	17.00	85.0°	10.00	48.0°
51.02	92.0	26.70	105.0	20.00	96.0	15.30	88.0
55.00	96.0	30.00	114.0	25.14	115.0	20.00	107.0
60.00	103.0	40.00	127.0	30.20	127.0	30.80	136.0
70.00	108.0	50.00	133.0	40.00	135.0	40.00	141.5
80.04	111.0	60.11	135.0	50.10	139.0	50.20	145.0
90.00	96.0	70.00	134.5	60.00	140.0	60.00	146.0
95.00	64.0	80.00	130.0	70.00	141.0	70.00	147.0
		90.00	112.0	80.00	138.0	80.00	141.0
				90.00	119.0	90.00	124.0
				93.12	105.0	95.00	96.0

Section 5 60% BA, 40% An		Section 6 70% BA, 30% An		Section 7 80% BA, 20% An	
13.00	80.0°	15.00	83.0°	14.00	74.0°
15.20	95.0	20.00	110.0	20.00	99.0
20.00	113.0	30.09	133.0	30.00	125.0
30.00	137.0	40.00	142.0	40.00	135.0
40.00	146.0	50.00	146.0	50.20	138.0
50.00	148.0	60.00	147.0	60.00	140.0
60.13	149.0	70.00	145.0	70.00	141.0
70.00	148.0	80.00	141.0	80.00	139.0
85.00	139.0	90.00	128.0	90.06	127.0
90.00	127.5	95.30	102.0	95.00	101.0
95.00	102.0			96.00	91.0
96.00	88.0				

Four solubility isotherms of the given ternary system at temperatures 80, 100, 135 and 145° were constructed from the polytherms obtained. As Figure 3 shows, the isotherms at 80 and 100° start from breaks in the solubility of the binary system benzoic acid—water and pass inside the prism of the ternary system. The isotherms at 135 and 145° have the form of closed curves. In the ternary system being studied, therefore, the separation of phases in the binary system benzoic acid—water is homogenized by the antipyrine; at the same time an upper ternary critical point is formed. The latter lies at 150° and corresponds to a composition of 23% benzoic acid, 17% antipyrine and 60% water.

Each isotherm shows minima for the mutual solubility of water and mixtures of benzoic acid and antipyrine. The minima of all the isotherms lie in the binary system benzoic acid—antipyrine at the composition of a complex in which the ratio between the molecules of the components mentioned is 2 : 1. The turning points of the isotherms, therefore, do not lie at the composition of a compound which is established from the melting point curves of the predominating system. A similar phenomenon is observed even on the isotherm at 80°, which is situated a total of 14° above the melting point of the compound detected from the fusibility. On the strength of this the above deviation cannot be ascribed to thermal dissociation of the compound, as takes place in systems with irrational turning points. It can only be explained by the influence of the strongly polar solvent – water – on the reacting system. To confirm this suggestion, the interaction of the binary system benzoic acid–antipyrine was studied in the non-polar solvent – benzine.

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* In both Tables, BA — benzoic acid, An — antipyrine.

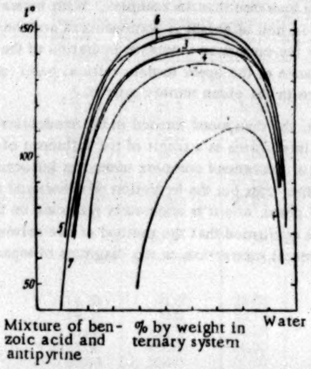

Fig. 1. Solubility polytherms of the ternary system benzoic acid–antipyrine–water.

In the ternary system benzoic acid–antipyrine–benzine, seven polythermal sections were studied. The numerical data obtained are given in Table 2 and the polythermals of separation of phases are shown in Figure 2. In the majority of the polythermals the maxima of the mutual solubility of the liquid phases are situated at high temperatures and could not therefore be determined. The polythermal maxima were found only in sections 6 and 7, in which they are displaced towards the benzine edge. In all the sections (except 7) the mutual solubility of the liquids is only very slightly dependent on temperature, so that all the solubility curves rise steeply.

Three isotherms of separation of phases at temperatures 100, 130 and 150°, shown in Figure 4, were constructed from the polythermals obtained. In this case the separation of phases in the binary system antipyrine–benzine is homogenized by the benzoic acid. As a result of this all the isotherms start from breaks in the solubility of the binary system antipyrine–benzine and are closed inside the prism of the ternary system. Each isotherm shows minima for the mutual solubility of benzine and mixtures of benzoic acid and antipyrine. The minima of all the isotherms lie in the binary predominating system benzoic acid–antipyrine on the composition of the compound established from the fusibility diagram (i.e., of composition 1 : 1), and this also fixes its presence in the liquid phase of the ternary system. The presence of the above-mentioned minima on the isotherms of separation of phases and the concentric decrease of the latter with increase in temperature indicate that in the ternary system being studied there exists an upper ternary critical point. This, however, could not be detected since it is situated at high temperatures.

Comparison of the isotherms of separation of phases in the 2 ternary systems described shows that solvents of different polarity show a specific and qualitatively different influence on the interaction in the reacting system benzoic acid–antipyrine. In the ternary system benzoic acid–antipyrine–benzine, in the non-polar solvent, benzine, the most highly developed processes are those of association of molecules and dissociation of the associated molecules. These processes take place in the predominating system and also in the reaction of this with the third component. As a result of this the antipyrine benzoate, fixed by the fusibility diagram, is present in the liquid phase of the given ternary system and is stabilized in it by association processes. The minima of the separation of phases lie at the composition of the compound, which is thus established. The formation of minima on the isotherms of separation of phases is explained by the more extensive dissociation of the components of the predominating system than of its compound. Studies by a number of authors [6, 7] have shown that benzoic acid exists in hydrocarbon solutions in the form of double molecules. The dissociation of the associated molecules of benzoic acid leads to its unlimited mutual solubility in benzine. The dissociation processes in the system antipyrine–benzine lead to homogenization of the separation of phases.

The ternary system benzoic acid–antipyrine–water contains the polar solvent – water. The components of the reacting system, benzoic acid and antipyrine, are capable of being extensively hydrated; thus, antipyrine has the tertiary amine groups, while benzoic acid has the carboxyl group and is highly polar (dipole amount equal to $1 \cdot 10^{18}$ [8]). As a result of this, hydration processes are the most highly developed in the ternary system. These processes determine the character of the interaction between the predominating system and the third component, i.e., the character of the influence of the polar aqueous medium on the interaction in the reacting binary system. On the one hand, the extensive hydration of antipyrine, which leads to its unlimited solubility in water makes the stabilization of the compound with composition 1: 1 in the liquid phase impossible. On the other hand, the separation of phases in the binary system benzoic acid–water weakens the interaction between its components. As a result of these factors and the high polarity of the benzoic acid, the interaction between the acid and the compound with composition 1 : 1 is strengthened and a complex with composition 2: 1 formed (2 molecules of benzoic acid to 1 molecule of antipyrine). The interaction between benzoic acid and antipyrine is a process of salt formation in which the functional groups react with one another. The complex obtained is responsible for the appearance of the solubility minima on the isotherms of the separation of phases since the components of the reacting system are more extensively hydrated than its complex. With increase in temperature in the binary system benzoic acid–water, the separation of phases is homogenized and the hydration of the benzoic acid is increased. This process, together with the continued extensive hydration of the antipyrine, leads to dissociation of the complex and to the disappearance of the upper ternary critical point for which it is responsible; in this way complete homogenization takes place in the given ternary system.

Thus in the ternary system benzoic acid–antipyrine–water, the compound formed in the predominating system is reflected inaccurately on the isothermals of separation into phases as a result of the influence of the polar solvent on the interaction. This results from the formation of the second complex under the influence of water. Replacement of the latter by the non-polar solvent, benzine, cuts out the hydration processes and the secondary interaction of the compound, stabilizes it in the liquid phase, and it is accurately reflected on the solubility isotherms of the ternary system. At the same time it is confirmed that the method of two solvents can indeed be used to avoid the anomalous reflection of the chemical interaction on the diagrams of separation of phases.

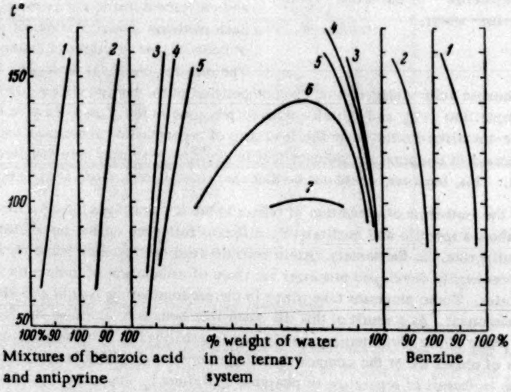

Fig. 1. Solubility polytherms of the ternary system benzoic acid–antipyrine–

In working out the method of two solvents [1], it has been shown that when the solvents are changed, transformation of the ternary systems from one type to another takes place. A ternary system with an upper ternary critical point was converted into a system with a synclinal singular edge. The present work confirms the possibility of the transformations indicated among ternary systems with an upper ternary critical point, which both the systems described contain. In this case a system with chemical interaction inaccurately reflected is converted into a system in which it is accurately reflected.

TABLE 2

Polytherms of the System Benzoic Acid–Antipyrine–Benzine

Section 1		Section 2		Section 3		Section 4	
20% BA, 80% An		30% BA, 70% An		39.3% BA, 60.7% An		50% BA, 50% An	
benzine (% by weight)	temperature of separation of phases	benzine (% by weight)	temperature of separation of phases	benzine (% by weight)	temperature of separation of phases	benzine (% by weight)	temperature of separation of phases
5.07	71.0°	7.00	75.0°	7.00	84.0°	7.20	63.0°
7.00	85.5	8.06	88.0	8.00	95.0	10.00	91.0
10.40	113.0	13.00	137.0	10.10	119.0	12.06	110.0
15.00	148.0	15.00	156.0	13.00	153.0	14.00	125.0
16.00	155.0	85.00	155.0	86.00	157.0	17.00	151.0
85.00	152.5	90.20	140.0	90.00	140.0	80.00	165.0
90.00	136.0	95.00	112.0	95.00	110.0	90.00	137.0
95.00	110.0	97.00	90.0	97.00	90.0	95.00	113.0
96.00	89.0					97.00	95.0

Section 5		Section 6		Section 7	
60% BA, 40% An		70% BA, 30% An		80% BA, 20% An	
12.20	81.0°	26.00	99.0°	60.00	101.0°
15.00	99.0	30.10	106.0	70.00	102.0
20.00	127.5	40.20	120.0	80.00	101.0
24.00	150.0	50.90	130.0		
80.40	154.0	60.00	138.0		
90.00	125.0	70.00	141.0		
95.00	98.0	80.00	135.0		
		90.00	114.0		
		93.00	95.0		

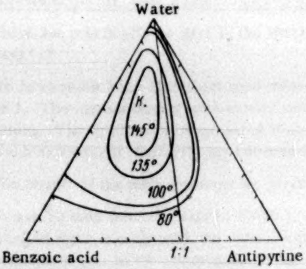

Fig. 3. Solubility isotherms of the ternary system benzoic acid–antipyrine–water.

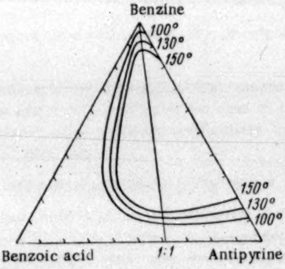

Fig. 4. Solubility isotherms of the ternary system benzoic acid–antipyrine–benzine.

SUMMARY

1. A study has been made of the equilibrium between the liquid phases in the ternary system benzoic acid–antipyrine–water. This shows a surface of separation of phases adjoining the face of the binary system benzoic acid–water, with an upper ternary critical point. It has been found that the interaction in the binary predominating system benzoic acid–antipyrine is inaccurately reflected on the surface of separation of phases of the ternary system as a result of the powerful influence of the polar solvent – water – on the system.

2. A study has been made of the equilibrium between the liquid phases in the ternary system benzoic acid–antipyrine–benzine. In this ternary system the isotherms of separation of phases show solubility minima situated at the composition of the compound of the predominating system; the compound is accurately reflected on the surface of separation of phases.

3. It has been shown that the method of two solvents is a reliable method for avoiding inaccurate reflection of chemical interaction in the predominating system on the surface of separation of phases in a ternary system.

4. It has been confirmed that in using the method of two solvents transformation of ternary systems from one type to another takes place. A transformation of ternary systems with an upper ternary critical point has been achieved; a system with chemical interaction inaccurately reflected has been converted into a system with the interaction accurately reflected.

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** In Russian.

THE APPLICATION OF CERTAIN PHYSICOCHEMICAL METHODS TO THE STUDY OF POLYNUCLEAR COMPLEX COMPOUNDS OF COBALT AND CHROMIUM

M. S. Skanavi-Grigoryeva and I. P. Staroverova

One fairly extensive group of complex compounds is that formed by polynuclear complex compounds in which, unlike the usual complexes, there is not one complex-forming center, but two or more.

From the synthesis of these compounds and also from a detailed study of the products of their decomposition under the influence of powerful reagents such as hydrochloric and sulfuric acid, it is possible to assess the structure of polynuclear complexes and their derivatives with a high degree of accuracy. This however is insufficient, and for more convincing conclusions regarding their structure, examination by physicochemical methods is required.

Up to the present time no-one has carried out a thorough systematic physicochemical study of polynuclear complex compounds, unless we consider isolated works, such as, for example, measurements of magnetic susceptibility [1] and absorption spectra of aqueous solutions of certain polynuclear complexes of cobalt [2, 3]. At the same time many physicochemical methods for the examination of the structure of molecules and the nature of the bonds in them have been worked out for the study of the usual complex compounds (mononuclear).

Interest has been attached to the study of certain polynuclear complexes by different physicochemical methods to examine the accuracy of the structures ascribed to them. This paper presents results of work on the measurement of the electrical conductivity and molecular weights (by the cryoscopic method) of eight water-soluble polynuclear compounds of cobalt and chromium.

Determination of the Electrical Conductivity

There are practically no data in the literature on the electrical conductivity of solutions of polynuclear compounds [4].

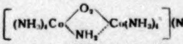
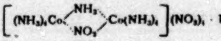
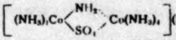
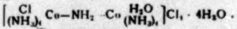
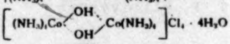
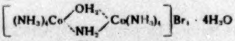
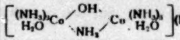
We have studied the electrical conductivity of aqueous solutions of the eight polynuclear compounds given in Table 1. The measurements were carried out at 25° within the first 7-10 minutes from the time of preparing the solutions. The solutions were prepared from twice-distilled water, whose electrical conductivity, measured before each experiment, normally lay between 2.20 and $4.69 \cdot 10^{-6}$ $\text{ohm}^{-1}\text{cm}^{-1}$.

The results of the measurements are given in Table 1 and represented graphically in Figures 1-4.

As can be seen from the data in Table 1, the numerical values of the electrical conductivity of the complexes studied agree closely with the values required on the basis of the classical work of A. Werner depending on the number of ions in the compound. In the majority of cases the molar conductivity increases regularly with dilution. A molar conductivity somewhat higher than that required by the classical work is observed for compounds 4 and 7, and at the same time it increases sharply with dilution. This can only be explained by the particular behavior of the substitutents in the inner sphere – the water and the chlorine. I. I. Chernyaev [5] points out the intensification of the amido reaction in mononuclear cobalt complexes in the case of those substituents which lead to migration of the hydrogen ion into the inner sphere.

Whereas in the majority of the compounds studied by us the electrical conductivity tends to a limiting value with dilution of the solution, in the case of the above-mentioned compounds it rises sharply (the curves corresponding to them have a steeper path than all the others). These values of the electrical conductivity are

TABLE 1

Specimen No.	Composition of the compounds	Molar conductivity at different dilutions		
		1000	2000	4000
1	 $\left[(NH_3)_4Co\langle{}^{O_2}_{NH_2}\rangle Co(NH_3)_4\right](NO_3)_4$	528	566	580
2	 $\left[(NH_3)_4Co\langle{}^{NH_2}_{NO_2}\rangle Co(NH_3)_4\right](NO_3)_4 \cdot H_2O$	514	549	574
3	 $\left[(NH_3)_4Co\langle{}^{NH_2}_{SO_4}\rangle Co(NH_3)_4\right](NO_3)_3$	373	379	383
4	 $\left[{}^{Cl}_{(NH_3)_4}Co-NH_2-Co{}^{H_2O}_{(NH_3)_4}\right]Cl_4 \cdot 4H_2O$	546	624	652
5	 $\left[(NH_3)_4Co\langle{}^{OH}_{OH}\rangle Co(NH_3)_4\right]Cl_4 \cdot 4H_2O$	527	569	603
6	 $\left[(NH_3)_4Co\langle{}^{OH_2}_{NH_2}\rangle Co(NH_3)_4\right]Br_4 \cdot 4H_2O$	510	548	584
7	 $\left[{}^{(NH_3)_3}_{H_2O}Co\langle{}^{OH}_{NH_2}\rangle Co{}^{(NH_3)_3}_{H_2O}\right](NO_3)_4$	557	672	750
8	$[(NH_3)_5Cr-OH-Cr(NH_3)_5]Cl_5 \cdot H_2O$	621	682	729

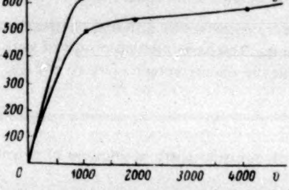
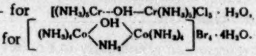


Fig. 1. Change in molar conductivity with dilution.

1 — for $[(NH_3)_5Cr-OH-Cr(NH_3)_5]Cl_5 \cdot H_2O$,

2 — for  $\left[(NH_3)_4Co\langle{}^{OH}_{NH_2}\rangle Co(NH_3)_4\right]Br_4 \cdot 4H_2O$.

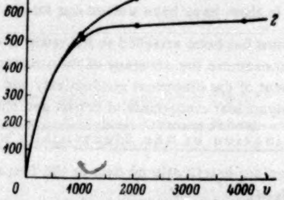
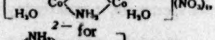
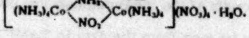


Fig. 2. Change in molar conductivity with dilution.

1 — for  $\left[{}^{(NH_3)_3}_{H_2O}Co\langle{}^{OH}_{NH_2}\rangle Co{}^{(NH_3)_3}_{H_2O}\right](NO_3)_4$,

2 — for  $\left[(NH_3)_4Co\langle{}^{NH_2}_{NO_2}\rangle Co(NH_3)_4\right](NO_3)_4 \cdot H_2O$.

characteristic of compounds with a greater number of ions than five. In the case of compound 4 it may be assumed that a compound giving rise to six ions is present in solution. It is probable that at high dilutions the chloride ion migrates completely from the inner to the outer sphere.

For a fuller characterization of electrical conductivity of the compounds studied by us, we may take the data obtained later by I. M. Reibel [6] on the change in electrical conductivity with time (at a dilution of 1 mole/1000 liters).

The data given in Table 2 show the greater stability of the first two compounds with time in solution at a given dilution agree with our observations on the change in electrical conductivity with dilution, which may be explained by the increase in dissociation of these substances with dilution as a result of hydrolysis of the complex cation, but not by decomposition of the complex.

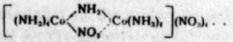
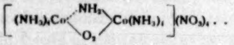
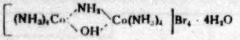
The considerable increase in electrical conductivity with time observed by I. M. Reibel for compound 3 is difficult to explain, the more so since our data show normal behavior for this compound in solution.

In this way the data obtained by us, together with Reibel's data, confirm fairly conclusively the accuracy of the compositions ascribed to the polynuclear compounds of cobalt listed above. These data may also be taken as indicating the considerable stability in solution of the majority of the cobalt compounds studied by us, at any rate over the time interval in which the measurements were made. The unstable compounds are those which contain, as addenda in the inner sphere, aquo groups or the easily washed-out chloride ions (Table 1, Compounds 4 and 7), or alternatively hydroxyl groups in the form of the easily broken bridge linkage (Compound 8).

Determination of Molecular Weights

The determination of the molecular weight is one of the most convincing proofs of the accuracy of a formula ascribed to a compound. For complex compounds however, this method has up to the present not always been available. The only method of determination which has found a place in the chemistry of complex compounds to any extent is the cryoscopic method; this, however, is only applicable in those cases where the full composition of the compound has already been established by chemical methods [7].

TABLE 2

Specimen No.	Composition of the compound	Molar conductivity at different times (in minutes)						
		0	15	20	30	35	45	60
1	 $\left[(NH_3)_4Co\begin{smallmatrix}NH_2\\NO_2\end{smallmatrix}Co(NH_3)_4\right](NO_3)_4$	529.2	529	—	527	527	—	—
2	 $\left[(NH_3)_4Co\begin{smallmatrix}NH_2\\O_2\end{smallmatrix}Co(NH_3)_4\right](NO_3)_4$	486.4	—	487	487	490.8	493	—
3	 $\left[(NH_3)_4Co\begin{smallmatrix}NH_2\\OH\end{smallmatrix}Co(NH_3)_4\right]Br_4\cdot 4H_2O$	477	—	558	—	560	562	572

There are several works in the literature on the determination of molecular weights [4,8] by the cryoscopic method. The molecular weights of a large number of complex compounds, including compounds of chromium, have been determined in this way by Petersen [9], who used the formula $M = C\frac{p}{\Delta t}$, where Δt – freezing point difference, p – percentage concentration of the solution and C – a constant equal to 45. This constant, calculated on the basis of Raoult's law, is applicable only to aqueous solutions and then only to concentrated solutions, since only when this latter condition was fulfilled did Petersen obtain more or less satisfactory results.

Pfeiffer [10] used Petersen's method of calculation in the determination of the molecular weights of ethylenediamine complexes of chromium. In view of the fact that the polynuclear complexes synthesized by us are insoluble in common organic solvents, we had to carry out the measurement of the molecular weights in aqueous solutions; the calculations from the experimental data obtained were carried out using Petersen's formula, and also using the formula usually applied in determinations by the cryoscopic method:

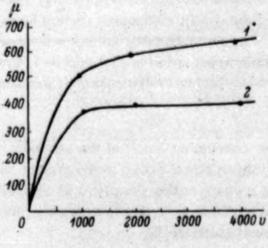
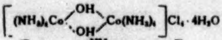
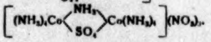


Fig. 3. Change in molar conductivity with dilution.

1 — for 
$\left[(NH_3)_4Co\genfrac{}{}{0pt}{}{OH}{OH}Co(NH_3)_4\right]Cl_4\cdot 4H_2O$

2 — for 
$\left[(NH_3)_4Co\genfrac{}{}{0pt}{}{NH_2}{SO_4}Co(NH_3)_4\right](NO_3)_3$.

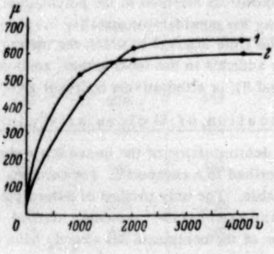
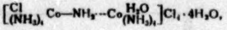


Fig. 4. Change in molar conductivity with dilution.

1 — for 
$\left[\genfrac{}{}{0pt}{}{Cl}{(NH_3)_4}Co-NH_2-Co\genfrac{}{}{0pt}{}{H_2O}{(NH_3)_4}\right]Cl_4\cdot 4H_2O$,

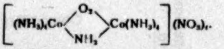
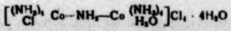
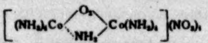
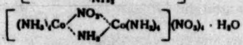
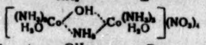
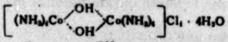
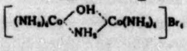
2 — for 
$\left[(NH_3)_4Co\genfrac{}{}{0pt}{}{O_2}{NH_2}Co(NH_3)_4\right](NO_3)_4$.

TABLE 3

Specimen No.	Composition of the compounds	g	p	Δt	M according to Petersen's formula	M calc. from the cryoscopic data	M calculated theoretically
1	 $\left[\genfrac{}{}{0pt}{}{(NH_3)_4}{Cl}Co-NH_2-Co\genfrac{}{}{0pt}{}{(NH_3)_4}{H_2O}\right]Cl_4\cdot 4H_2O$	0.1816 0.3513	0.60 1.15	0.076 0.168	355 310	603	537
2	 $\left[(NH_3)_4Co\genfrac{}{}{0pt}{}{O_2}{NH_2}Co(NH_3)_4\right](NO_3)_4$	0.2264 0.2626	0.75 0.78	0.089 0.088	379 396	742	550
3	 $\left[(NH_3)_4Co\genfrac{}{}{0pt}{}{NO_2}{NH_2}Co(NH_3)_4\right](NO_3)_4\cdot H_2O$	0.1712 0.1785	0.56 0.59	0.076 0.079	315 336	643	582
4	 $\left[\genfrac{}{}{0pt}{}{(NH_3)_3}{H_2O}Co\genfrac{}{}{0pt}{}{OH}{NH_2}Co\genfrac{}{}{0pt}{}{(NH_3)_3}{H_2O}\right](NO_3)_4$	0.1385 0.2818	0.46 0.96	0.043 0.084	482 499	—	537
5	 $\left[(NH_3)_4Co\genfrac{}{}{0pt}{}{OH}{OH}Co(NH_3)_4\right]Cl_4\cdot 4H_2O$	0.1774 0.2086	0.62 0.69	0.098 0.109	270 285	515	502
6	 $\left[(NH_3)_4Co\genfrac{}{}{0pt}{}{OH}{NH_2}Co(NH_3)_4\right]Br_4$	0.2659 0.2836	0.80 0.93	0.109 0.118	363 354	647	607
7	$[(NH_3)_5Cr-OH-Cr(NH_3)_5]Cl_5\cdot H_2O$	0.2818 0.3929	0.93 1.29	0.149 0.206	281 283	617	486

$M = \frac{K \cdot g \cdot 1000}{\Delta t \cdot q}$, where K – cryoscopic constant, g – sample weight q – solvent weight. The determination was carried out using a Beckmann thermometer, the temperature in the thermostat was kept at 5-6° below zero. The freezing point of the water was measured before each determination.

Table 3 shows the results of the determination of the molecular weights of seven polynuclear complex compounds prepared by us. The data in Table 3 show that the molecular weights calculated using Petersen's formula give totally unsatisfactory results. The reason for this is to be found in the fact that for such calculations, the measurements have to be carried out in solutions whose concentrations are relatively high, and, moreover, strictly defined. Lower and higher concentrations than those required by Petersen did not give good results. We were working, however, with compounds which are very sparingly soluble, especially at 0°.

From the data on the measurement of the electrical conductivity it is possible to calculate the degree of dissociation (α) and Van't Hoff coefficient (i) for the substances being studied and to introduce a correction for $\underline{i}$ in the values of the molecular weights obtained by us using the cryoscopic method (calculated from the usual formula). If it is assumed that the molar conductivity (μ) at dilution $\underline{v}$ = 4000 liters corresponds practically to that at infinite dilution (μ_∞), then $\alpha = \frac{\mu_v}{\mu_\infty}$, from which $\underline{i} = \alpha(n-1) + 1$, where $\underline{n}$ = number of ions into which the complex compound dissociates.

The data obtained in this calculation are given in Table 3. They show that the value of the molecular weight after multiplication by the Van't Hoff coefficient agrees fairly closely with that calculated theoretically. The greatest difference in the values of the molecular weights calculated theoretically and obtained experimentally is seen for the compounds with a peroxo-bridge, for the chromium compound with a hydroxo-bridge, and for diaquodiammino-α-ammino-α-hydroxodicobaltinitrate (Compound 4 in Table 3). For this last compound we did not even consider it possible to give the values obtained for the molecular weight. This compound is unstable in aqueous solution.

It should be noted that all the molecular weight values given above are very approximate, inasmuch as α has been calculated for the materials at 25°, while the molecular weight by the cryoscopic method was determined at a temperature somewhat below 0°. It is obvious that the measurement of the electrical conductivity and molecular weight should be carried out at the same temperature.

SUMMARY

1. It has been shown experimentally that physicochemical methods of study are suitable for the confirmation of the composition of polynuclear complexes suggested on the basis of the synthesis and analysis of these compounds.

2. The values obtained for the molar conductivity of aqueous solutions of eight polynuclear compounds confirm the generally accepted formulae for these compounds.

3. The application of the cryoscopic method for the determination of molecular weight to the study of polynuclear compounds is limited to a considerable degree. The application of the Petersen formula for the calculation of molecular weight is possible only in those cases where solutions with a concentration of 3-4% can be obtained at 0°. The calculation of the molecular weight by the cryoscopic formula gives satisfactory results when the number of ions, into which the compound dissociates in solution, is known; for this it is necessary to obtain data on the molar conductivity of the compound, from the data to determine the degree of dissociation and the Van't Hoff coefficient, and introduce a correction in the calculation of the molecular weight by the cryoscopic formula.

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THE REACTIONS OF DIMETHYLGLYOXIME WITH IRON (III) AND COPPER CATIONS IN AQUEOUS SOLUTIONS

A. M. Gurvich

Work undertaken in a continuation of a systematic study of compounds of dimethylglyoxime with metal cations by the chromatographic method [1, 2] has led to the discovery of new compounds not previously described in the literature – iron(III)-copperdimethylglyoximes and iron(III)dimethylglyoxime.

The Reaction of Dimethylglyoxime with Cations of Iron (III) and Copper in Weakly Acid Aqueous Solutions

In a study of the separation of metals on a carbon-dimethylglyoxime column [2] we discovered that when a mixture of solutions of Fe^{+++} and Cu^{++} salts was passed through such a column, a somewhat unusual phenomenon took place: at equal concentrations of these cations in the mixture, their break-through took place simultaneously; with an excess of Fe^{+++}, the latter broke through before the Cu^{++}, the interval increasing as the excess of Fe^{+++} was increased. With an excess of Cu^{++}, break-through took place simultaneously, as in the case of equal cation concentration. In attempts to explain this phenomenon, we undertook a study of the system $Fe^{+++} - Cu^{++} - H_2Dm$ in solution and discovered that the addition of dimethylglyoxime (H_2Dm) to a weakly acid mixture of solutions of Fe^{+++} and Cu^{++} salts brings about the formation of a red-brown coloration, whereas either of these solutions taken separately gives no such color.

For the study of this reaction we used the spectrophotometric method of "continuous variation" of Ostromislensky-Job [3, 4]. This method has been used to establish the composition of complex compounds of dimethylglyoxime with metal cations by a number of workers [5-11].

The Ostromislensky-Job method, as is well known, involves the determination of the turning point on the curve of the relationship between light absorption and solution composition, for which a photometer with an appropriate form of selected light filter is used to determine the optical density of a series of solutions of equal volume prepared by mixing the reacting substances in the form of solutions of identical molarity.

For the study of the reaction of H_2Dm with Fe^{+++} and Cu^{++} two series of solutions were prepared. In one of these the quantities of Fe^{+++} and Cu^{++}, which were taken in the form of 0.01 M solutions of their salts (chlorides or sulfates), were varied, while the quantity of H_2Dm remained constant (18 ml 0.004 M aqueous solution); the total volume of the mixture amounted to 20 ml. In the second series the $Fe^{+++}:Cu^{++}$ ratio equalled unity, i.e., it corresponded to the ratio at which the maximum was observed in the first series of solutions; a solution of Fe^{+++} and Cu^{++} salts with total cation concentration equal to 0.004 mmole/ml was mixed with 0.004 M H_2Dm solution so that the total volume of the mixture amounted to 9 ml. In the case of the chlorides each solution of a given series was diluted with a further 5 ml of water.

The H_2Dm was taken in the form of an aqueous solution, since in alcoholic solution the reaction of H_2Dm with metal cations may take place in different fashion from that in aqueous solution [12], and so for the study of complex formation it is undesirable to take a mixture of these solvents. We did not introduce added oxidant into the system, since the presence of this also may substantially change the course of the reaction, leading in a number of cases to the formation of compounds of dimethylnitroxime – a product of the oxidation of H_2Dm which has not yet been isolated. The presence of a small quantity of Fe^{++} cannot be of importance, since this cation does not react with H_2Dm at pH < 5 [7], and in our experiments the pH lay within the range 2.2-2.9.

It was established from preliminary measurements that the maximum of light absorption in solutions obtained by mixing Fe^{+++}, Cu^{++} and H_2Dm lies in the short-wave region of the spectrum; the optical density was therefore measured using a blue light filter ($\lambda_{eff.} = 478$ mμ).

The results of the measurements for the first series of solutions, given in Figure 1, show that Fe^{+++} and Cu^{++} form a compound with H_2Dm at a molar ratio of $Fe^{+++} : Cu^{++} = 1 : 1$, and this ratio does not depend on whether the Fe^{+++} and Cu^{++} are taken in the form of the chlorides or the sulfates. This result was confirmed in five experiments.

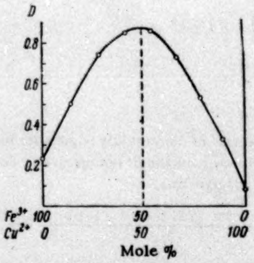

Fig. 1. The relationship between optical density and the ratio of the concentrations of trivalent iron and copper with a constant amount of dimethylglyoxime.

The results of the measurements of light absorption of the solutions of the second series are given in Figure 2, showing that for the chlorides the maximum of light absorption lies at the ratio $(Fe^{+++} + Cu^{++}) : H_2Dm = 2 : 1$, i.e., at the ratio $Fe^{+++} : Cu^{++} : H_2D_m = 1 : 1 : 1$; for the sulfates the light absorption is a maximum at the ratio $Fe^{+++} : Cu^{++} : H_2Dm = 1 : 1 : 2$. This result was confirmed in four experiments, from which it was also found that for the mixture $FeCl_3 + CuSO_4$ the ratio obtained was $Fe^{+++} : Cu^{++} : H_2Dm = 1 : 1 : 1$, i.e., the same as for the mixture $FeCl_3 + CuCl_2$.

We may thus postulate the existence of two complexes of iron (III) and copper with H_2Dm. These complexes are not extracted from aqueous solution by butyl alcohol, isoamyl alcohol, diethyl ether, ethyl acetate, toluene, xylene, chloroform, methylene chloride or dichloroethane.

The iron(III)-copperdimethylglyoximes have a comparatively low stability, at any rate in the pH range studied, as is shown by the rounded shape of the maximum on the composition–light intensity curves (Figure 1) (see [13]), and also by the spontaneous decomposition of the complexes on prolonged standing (these two phenomena may, however, be brought about by different processes). The compounds of H_2Dm with iron (III) and copper are not adsorbed by an anionite in the salt form; they are decomposed by Na-cationite, apparently, as the result of the exchange adsorption of Fe^{+++} and Cu^{++} and the consequent displacement of the equilibrium in the direction of dissociation of the complexes (at any rate, these complexes cannot be desorbed from the cationite column).

The H_2Dm molecules in iron(III)-copperdimethylglyoxime probably function as a "bridge" holding together the Fe^{+++} and Cu^{++}. The ability of H_2Dm to give complexes with two metals is indicated by the existence of the compound $FeCoC_{12}H_{19}O_6N_6$ [14], which Feigl [15] considers to be a binuclear compound whose structure may be represented by the formula $Dm = Fe - DmH - - - Co = Dm$ (the iron is trivalent here also). As Peshkova [16] points out, this compound is distinguished by a low stability.

It is apparently possible in principle to isolate the compounds of iron (III) and copper with H_2Dm in the solid state. Thus when the reaction is carried out between an equimolar mixture of Fe^{+++} and Cu^{++} salt solutions and dimethylglyoxime, taken in the form of a powder, in the presence of sodium acetate with heating on a water bath, there is formed a black (in the case of the sulfates) or a brown (in the case of a mixture of $FeCl_3 + CuSO_4$) precipitate, in which, after treatment with hot water and hot alcohol, Fe, Cu and N are detected; moreover, assuming that the N is present in the compound as a component of H_2Dm, we arrive at the ratio $Cu^{++} : H_2Dm = 1 : 2.13$ for the black precipitate and $Cu^{++} : H_2Dm = 1 : 1.06$ for the brown precipitate; the quantity of iron (in moles) in both cases, however, is considerably greater than the quantity of copper.

Both precipitates are insoluble in water, ethyl and butyl alcohols, diethyl ether and chloroform, but dissolve readily in dilute mineral acids with the formation of an intense red solution. The brown precipitate decomposes violently at 184°, and one of the decomposition products, containing iron, sublimes.

No more detailed chemical study of this reaction was carried out.

The Reaction of Dimethylglyoxime with Iron (III)

The only report that dimethylglyoxime is capable of reacting with trivalent iron is that of Braley and Hobard [17]. These authors state that Fe^{+++} gives a pink coloration with H_2Dm. They give no other data at all on this compound. Other workers have not been able to confirm the observations of Braley and Hobard [16]. Babko shows quite definitely [5] that Fe^{+++} gives no complex with H_2Dm and reacts with it only in the presence of an oxidizing agent, forming a complex with an unstable product of the oxidation of dimethylglyoxime. Kuras and Ruzicka [18], carrying out the reaction between $FeCl_3$ and H_2Dm in the presence of bromine water, obtained a compound of composition $FeC_{12}H_{21}O_9N_6$, which they consider to be a derivative of dimethylglyoxime.

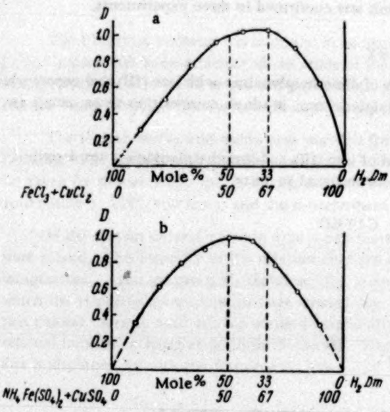

Fig. 2. Relationship between optical density and the ratio of $[Fe^{+++}] + [Cu^{++}]$ to $[H_2Dm]$ at $[Fe^{+++}]:[Cu^{++}] = 1$. a) in the system $FeCl_3-CuCl_2-H_2Dm$, b) in the system $NH_4Fe(SO_4)_2-CuSO_4-H_2Dm$.

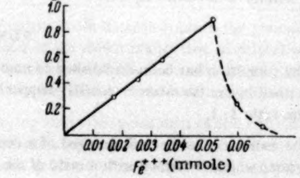

Fig. 3. Relationship between optical density and quantity of trivalent iron with unchanged amount of dimethylglyoxime.

Using chromatographic columns of a mixture of alumina and H_2Dm (in the ratio 10:1) [2], we discovered that a solution of a trivalent iron salt forms a brown zone on these columns, which is distinguished by the shade of the color from the brown zone formed by divalent iron (the latter gives in addition a narrow pink zone under the brown), and also from the yellow zone of Fe^{+++} on a column of alumina. We were at first unable to detect the formation of a compound of Fe^{+++} and H_2Dm in solution; as in the experiments described by Babko [5], when ammonia was added to a mixture of Fe^{+++} salt solution and an alcoholic solution of H_2Dm, a precipitate of hydrated iron (III) oxide was obtained.

When ammonia was added to the weakly acid solutions in which the reaction of H_2Dm with Fe^{+++} and Cu^{++} was studied by the method of "continuous variation" (see above), we discovered that the Fe^{+++} was not precipitated in all the cases where the ratio $H_2Dm:Fe^{+++}$ was greater than unity, including a solution which contained no Cu^{++}. It turned out that when ammonia was added to a mixture of 0.004 M aqueous H_2Dm solution and 0.1 M $FeCl_3$ solution with a molar ratio $H_2Dm:Fe^{+++} > 1$, a transparent orange-red solution was formed, which did not become turbid on prolonged standing and which diffused through a film formed from 4% collodion. When the reaction was carried out with more dilute Fe^{+++} solutions, a large excess of H_2Dm was required. Increase in the concentration of the ammonia brought about no change in the solution. On the other hand, the addition of ammonium chloride led to precipitation of the hydroxide. In aqueous alcohol medium with a large alcohol content the dimethylglyoxime complex of trivalent iron is not formed. Thus if 12 ml 0.004 M aqueous H_2Dm solution and 5 drops of 25% ammonia are added to 2 ml 0.01 M $NH_4Fe(SO_4)_2$ solution, a transparent orange-red solution is formed.* If, however, instead of the 12 ml of aqueous H_2Dm solution we use 12 ml of alcoholic solution of the same concentration, then when the ammonia is added a precipitate of ferric hydroxide is obtained from the mixture of the Fe^{+++} salt and H_2Dm.

In view of the fact that the considerable dilution of the aqueous H_2Dm solution, which takes place when it is mixed with the Fe^{+++} salt solution, has an unfavorable effect on the formation of iron (III) dimethylglyoxime, we studied the composition of this compound after preparing a series of solutions using one and the same quantity – 15 ml – of 0.004 M aqueous H_2Dm solution (0.06 mmole H_2Dm) with a varying quantity of 0.1 M $FeCl_3$ solution (from 0.2 to 0.8 ml). The mixture was brought to one and the same volume (15.8 ml), 5 drops of 25% ammonia were added and 10 ml of each solution was diluted with water in the ratio 5: 4.

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*The pink coloration observed by Braley and Hobard [17], has evidently no relation to the compound observed here.

Figure 3 shows the results of the measurement of the optical density of the solutions carried out 5 days after their preparation ($\lambda_{eff.}$ 478 mμ). The part of the curve shown by the dotted line corresponds to points obtained in the determination of the light absorption in solutions above a precipitate of iron (III) hydroxide. The sharp fall in optical density in this part of the curve is evidently explained by the fact that the hydroxide adsorbs the complex.

It can be seen from Figure 1 that the precipitation of $Fe(OH)_3$ begins at a H_2Dm: Fe^{+++} ratio close to unity, while up to this point the relationship between color intensity and Fe concentration obeys the Lambert-Beer law fairly well. The onset of the precipitation of ferric hydroxide in undiluted solutions corresponds more strictly to the ratio $H_2Dm:Fe^{+++}$ 1: 1. This result was confirmed in three experiments.

SUMMARY

1. The formation has been established of compounds of dimethylglyoxime with iron (III) and copper which are not described in the literature – iron(III)-copperdimethylglyoximes, in whose composition these metals are present in the ratio 1: 1.

2. The existence has been discovered of a compound of iron (III) and dimethylglyoxime, not described in the literature, which is formed with a ratio of the components equal to unity.

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* Original Russian pagination. See C. B. Translation.

** T.p. = C. B. Translation pagination.

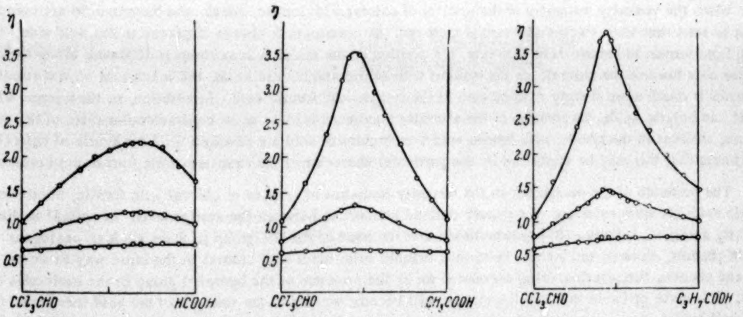
THE VISCOSITY OF BINARY SYSTEMS WITH CHLORAL. VI

V. V. Udovenko and R. I. Khomenko

The literature contains works on the condensation of chloral with organic acids in the presence of catalysts [1,2]. Interest has been attached to the study of the character of the direct interaction of chloral with organic acids. With this aim we have studied the viscosity of the systems chloral–formic acid, chloral–acetic acid and chloral–butyric acid. The system chloral–nitromethane has also been studied for comparison.

The formic and acetic acids were purified first by drying with subsequent distillation and then by fractional freezing. The butyric acid and the nitromethane were dried and subjected to repeated distillation. The material taken for the work had the following constants: the formic acid melted at 8.4°, the acetic at 16.6°, the butyric acid boiled at 161° (730 mm), and the nitromethane at 98.7° (721 mm).

In the system chloral–formic acid a considerable evolution of heat was observed when the components were mixed. The viscosity of the mixture changed at first and became constant after nine days storage at room temperature. After preparation, therefore, the mixtures were sealed in ampoules and stored for 10 days, after which the viscosity measurements were carried out. The results of the measurement of the viscosity of the system chloral–formic acid are represented graphically in Figure 1. The viscosity isotherms pass through an irrational maximum lying at 33 mole % chloral. When the temperature is raised the maximum becomes flatter and is displaced towards the formic acid side. The density isotherms of this system pass through a maximum.



Viscosity of the systems: chloral–butyric acid, chloral–acetic acid and chloral–formic acid at 25, 50 and 75°.

In the system chloral–acetic acid evolution of heat was again observed when the components were mixed. The viscosity of the mixtures acquired a constant value only on the eleventh day after their preparation. For the system chloral–acetic acid, therefore, the mixtures, sealed in ampoules, were kept in a boiling water bath for two weeks. The viscosity isotherms of this system have a sharply defined irrational maximum situated at 54 mole % chloral. When the temperature is increased the viscosity maxima become flatter and are slightly displaced in the direction of the acetic acid. The density isotherms have the form of curves concave towards the composition axis.

In the system chloral–butyric acid the viscosity becomes established much more rapidly and reaches a constant value on the second day after their preparation. The viscosity of the mixtures was therefore measured on the third day after their preparation. The viscosity isotherms of the system chloral–butyric acid have a sharply defined irrational maximum situated at 57 mole % chloral. When the temperature is increased the viscosity maximum becomes flatter and is slightly displaced towards the butyric acid. The density isotherms of this system are concave towards the composition axis.

In the system chloral–nitromethane the viscosity does not change with time, so that its measurement was made immediately after the preparation of the mixture.

The viscosity isotherms at all temperatures have the form of straight lines, while the density isotherms are concave towards the composition axis (see Table).

The System Chloral–Nitromethane

Chloral concentration (mole %)	Viscosity			Density		
	25°	50°	75°	25°	50°	75°
0.00	0.6215	0.4845	0.3991	1.1301	1.0981	1.0653
10.02	0.6610	0.5186	0.4178	1.1927	1.1593	1.1245
20.03	0.7023	0.5507	0.4429	1.2532	1.2184	1.1823
29.63	0.7591	0.5793	0.4664	1.3008	1.2643	1.2297
40.04	0.8043	0.6238	0.4886	1.3461	1.3083	1.2726
49.66	0.8435	0.6316	0.5017	1.3760	1.3377	1.3015
58.33	0.8874	0.6661	0.5223	1.4050	1.3659	1.3278
69.48	0.9389	0.6895	0.5376	1.4372	1.3918	1.3566
80.07	0.9876	0.7155	0.5654	1.4633	1.4222	1.3834
89.65	1.0285	0.7491	0.5800	1.4896	1.4444	1.4032
100.00	1.0552	0.7641	0.5885	1.5013	1.4603	1.4186

When the viscosity isotherms of the systems of chloral with formic, acetic and butyric acid are compared, it can be seen that when the temperature is increased the maximum is always displaced to the acid side. On going from formic to butyric acid, however, the position of the viscosity maximum is displaced along the composition axis towards the chloral. In the systems with acetic and butyric acids, the maximum on the viscosity isotherms is much more sharply defined than in the system with formic acid. In addition, in the systems with acetic and butyric acids, the position of the viscosity maximum is close to an equimolecular ratio of the components, whereas in the system with formic acid 2 molecules of acid are required for 1 molecule of chloral. It is probable that this may be explained by the particular character of the structure of the formic acid molecule.

The presence of the maximum on the viscosity isotherms of systems of chloral with formic, acetic and butyric acids provides evidence of a sharply defined interaction between the components. In optical studies on the fatty acids, M. I. Batuev [3] has established that the bond of the OH-group in these acids is analogous to that in phenols, alcohols and water. From this, organic acids react with chloral in the same way as water, alcohols and phenols, the reaction being accounted for by the presence of the hydroxyl group in the molecules of the acids. It is quite probable that this interaction will become weaker as the strength of the acid increases. Chloral, as is well known, does not react with strong acids, for example, sulfuric acid. This may explain the fact that the maximum on the viscosity isotherms is less sharply defined in the system with formic acid than in the systems with acetic and butyric acids.

In the system chloral–nitromethane the viscosity isotherms are straight lines and consequently if any interaction of the components takes place it is extremely poorly defined. It is known that under the action of alkalis the nitromethane molecule may rearrange to the isomeric aci-form. If the chloral exhibited basic properties, it would interact with the aci-form of the nitromethane. Since there is no such interaction, the chloral does not exhibit basic properties relative to the nitromethane. It may be suggested that the chloral exhibits acidic properties relative to organic substances so that it does not bring about the conversion of the nitromethane to the aci-form. This suggestion also does not agree with the experimental data. Indeed, in this case the chloral should exhibit the properties of a strong acid, since it does not react with sulfuric acid and forms a compound with organic acids. The question then arises, why then does it not react chemically with ethers and ketones with which strong acids readily form molecular compounds. From a comparison of the data from all the systems with chloral as a component, it must be admitted that the interaction of chloral with different classes of organic compound is not an acid-base reaction [4].

When an examination is made of all the systems whose viscosity we have studied in which chloral is taken as one of the components, it must also be noted that the chloral undergoes chemical interaction only with substances which contain the hydroxyl group in the molecule.

SUMMARY

1. A study has been made of the viscosity of the systems chloral–formic acid, chloral–acetic acid, chloral–butyric acid and chloral–nitromethane at 25, 50 and 75°.

2. It has been established that chloral interacts with formic, acetic and butyric acids.

3. Taking all the systems with chloral which we have studied earlier as examples, it has been shown that in direct interaction, the chloral forms chemical compounds only with substances which contain the hydroxyl group in the molecule.

4. The interaction of chloral with different hydroxyl-containing substances cannot be regarded as an acid-base reaction.

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THE ISOMERIZATION OF POLYMETHYLENIC HYDROCARBONS UNDER THE INFLUENCE OF ALUMINUM CHLORIDE

XX. THE ISOMERIZATION OF SPIRO-(4,5)-DECANE

M. B. Turova-Polyak, I. E. Sosnina and T. P. Yutkina

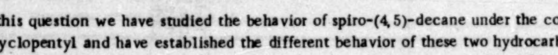
The catalytic changes undergone by spirane hydrocarbons have been little studied. The only data on spiro-(4,5)-decane are those on its behavior under conditions of dehydrogenative catalysis in the presence of selenium [1,2], platinized and palladized charcoal [2,3]. The product of dehydrogenation in all cases in naphthalene. The formation of naphthalene by the dehydrogenation of spiro-(4,5)-decane can only be assumed to take place as the result of preliminary contact isomerization of the spiro-(4,5)-decane to decahydronaphthalene with subsequent dehydrogenation of this to naphthalene.

In an earlier work [4] we have shown that decahydronaphthalene is obtained by the interaction of dicyclopentyl with aluminum chloride. The reaction was accompanied by the liberation of much heat. The temperature of the reaction mixture rose to 100° without preliminary heating. The reaction was complete in a few minutes. We suggested that this isomerization takes place via a stage involving the formation of spiro-(4,5)-decane, which is then isomerized to decahydronaphthalene in the presence of the aluminum chloride. No spiro-(4,5)-decane was detected, however, in an analysis of the products of the isomerization of dicyclopentyl using Raman spectra methods. This does not disprove our hypothesis for the mechanism of dicyclopentyl isomerization, with the condition that the rate of isomerization of the spiro-(4,5)-decane is very rapid.

To clarify this question we have studied the behavior of spiro-(4,5)-decane under the conditions of the isomerization of dicyclopentyl and have established the different behavior of these two hydrocarbons. The interaction of spiro-(4,5)-decane with aluminum chloride is not accompanied by the evolution of heat. No isomerization of the hydrocarbon takes place at room temperature. Only by heating the reaction mixture at 50° is decahydronaphthalene (the trans form) found in the reaction products to the extent of approximately 70%. At 75° (the optimum temperature) the isomerization is practically complete. The yield of trans-decahydronaphthalene rises to 93-94%. Increase of the temperature to 100° brings about the formation, together with decahydronaphthalene, of products of further isomerization, in which the presence of 2,2'-dimethyldicyclo-(0,3,3)-octane is indicated. As is known [5], a similar isomerization is possible on prolonged interaction of decahydronaphthalene and aluminum chloride. It should be noted that in the products of the isomerization of dicyclopentyl there is found, together with trans-decahydronaphthalene, a certain amount of the cis-form of the hydrocarbon, whereas in the isomerization of spiro-(4,5)-decane only trans-decahydronaphthalene is formed.

From the results obtained it may be taken that a spirane hydrocarbon system is considerably more stable in the interaction with aluminum chloride than such dicyclic hydrocarbons as cis-decahydronaphthalene [6] and dicyclopentyl [4].

We picture the isomerization of spiro-(4,5)-decane into decahydronaphthalene in the presence of aluminum chloride as taking place according to the same scheme as that proposed by N. D. Zelinsky and N. V. Elagina [3] for the contact isomerization of the same hydrocarbon under the conditions of dehydrogenative catalysis.



EXPERIMENTAL

The synthesis of spiro-(4,5)-decane was carried out according to the method described by N. D. Zelinsky and N. V. Elagina [3]. It was distilled at 15 mm on a column with an efficiency of 70 theoretical plates, and then studied by the Raman spectrum method (see Table 1 for constants). The intensity of the lines was determined visually and expressed on an arbitrary ten-division scale.

Spectrum of spiro-(4,5)-decane: 199(0.8), 224(0.5), 242(0), 276(0), 302(18), 357(10), 373(0), 387(0;d), 397(0), 408(1;d), 421(10; d), 455 (4; d), 480(0), 518(25), 547(0; d), 573(0; d), 587(0.5; d), 595(0.5; d), 603(0.5 d), 621(0; d), 635(0; d), 671(0.5), 713(15; br), 746(0; d), 784(5; d), 792(0; d), 822(12; d), 846(12; d), 878(0; d), 901(18; br), 930(1.5; d), 970(0.5), 992(18; br), 1023-1038 (50; br), 1076(18), 1095(20), 1117(0), 1133(0), 1144(15; d), 1157(15; d), 1170(15; d), 1183(3; d), 1196(2; d), 1219(4; d), 1241(0.8), 1258(25), 1268(25; d), 1280(0.5; d), 1296(0.5), 1332(2.5; d), 1347(15), 1358(0; d), 1382(0; d), 1397(0; d), 1439(60; br), 1443-1454(60; br).

The spectrum obtained practically corresponds to Batuev's spectrum of spiro-(4,5)-decane [7]. The additional weak unresolved lines in our spectrum may be ascribed to the different method of working.

The isomerization of the spiro-(4,5)-decane was carried out in the apparatus used by us for the previous work [8]. The molar ratio of aluminum chloride to hydrocarbon in all the tests was 1 : 3. The reaction mixture was stirred for 15-18 hours. In the experiments at 50, 75 and 100° it was heated on a water bath. The difficulty in studying the reaction products lay in the fact that the constants of the original spiro-(4,5)-decane and the isomerization product obtained (trans-decahydronaphthalene) are close to one another. The method of dehydrogenative catalysis was not used for the analysis in this case since spiro-(4,5)-decane is converted to naphthalene on dehydrogenation [3]. Since the characteristic lines of spiro-(4,5)-decane (302, 518, 713, 901, 1023-1038 cm^{-1}) and decahydronaphthalene (406, 493, 753, 846, 875 cm^{-1}) differ from one another the reaction was conveniently analyzed using the Raman spectra method. The data on the distillation of the reaction products, the constants of the original hydrocarbon and the constants of the possible isomerization products are given in Table 1.

TABLE 1

Hydrocarbons	Boiling point at 760 mm	Yield of reaction product (% orig. hydrocarbon)	n_D^{20}	d_4^{20}	MR_D found (cald. for $C_{10}H_{18}$ 43.98)
Original hydrocarbon	185° (64.5—64.7 at 13.5 mm)	—	1.4712	0.8779	43.96
Experiment I	185.5—186	88	1.4715	0.8778	43.98
Experiment II	185—186	85	1.4712	0.8770	44.00
Experiment III	184.5—185.5	84	1.4705	0.8725	44.08
Experiment IV	183.5	85	1.4688	0.8723	44.04
Experiment V					
1st fraction	to 172,	12	1.4549	0.8387	44.63
2nd fraction	172—182	18	1.4629	0.8559	44.40
3rd fraction	182—184	13	1.4652	0.8624	44.25
4th fraction	184—186	15	1.4668	0.8661	44.19
5th fraction	186—187.5	17	1.4694	0.8760	43.91
Spiro-(4,5)-decane [3]	185—186 (769 mm)	—	1.4698	0.8766	43.90
trans-Decalin [11]	185.3	—	1.46968	0.8700	44.24
cis-Decalin [11]	193.3	—	1.48113	0.8970	
cis-2,2'-dimethyldicyclo-(0,3,3)-octane [9]	166—167	—	1.450	0.838	44.25

Experiments I and II were carried out at 0° and room temperature (20-25°). When the spiro-(4,5)-decane was added to the aluminum chloride no noticeable change was observed: the temperature of the reaction mixture remained constant, the external appearance of the aluminum chloride was unchanged. After the mixture had been stirred for 15 hours, the constants of the reaction products of experiments I and II and their spectra were also practically unchanged (Table).

Experiment III was carried out at 50° for 15 hours. After appropriate purification the reaction product was distilled from metallic sodium and its constants determined (Table 1). The specific gravity of the reaction product is considerably lower than the specific gravity of the original spiro-(4,5)-decane, which indicates a change in the structure of the latter.

The spectrum of the product showed the appearance of lines characteristic of trans-decahydronaphthalene, while the lines characteristic of spiro-(4,5)-decane were weakened:

242(0.2), 276(0.2), 302(12; br), 325(0.2), 357(0.2), 388(0.2), 406(15), 421(0.2), 455(0.3), 480(0.3), 495(12), 518(4), 573(0.1), 587(0.1), 598(0.1), 706(2.5; br; d), 713(2.5; d), 752(11), 795(0.2), 808(0.2), 822(0.3), 848(10), 875(3), 901(3; br; d), 930(0.5; d), 962(0.2), 996(6; br; d), 1023-1038(6; br), 1057(13; br), 1076(4; d), 1085; (4; d), 1095(4; d), 1107(0.2), 1117(0.2), 1142(0.5), 1149(0.8), 1154(0.2), 1162(6; br), 1165(6), 1183(0.5), 1196(0.1), 1232(3), 1258(12), 1267(0.2), 1279(2), 1332(0.2), 1347 (2.0), 1359(4.0), 1382(0.2), 1433(3), 1443 (20; br), 1465(0.5).

It follows from analysis of the spectrum that the reaction products of this experiment contain approximately 70% trans-decahydronaphthalene and 30% unchanged spiro-(4,5)-decane.

Experiment IV was carried out at 75°. The constants of the reaction product are given in Table 1.

Spectrum of the product obtained: 197(0), 299(2), 352(1.5; d), 406(50), 421(0), 435(0.5), 455(0), 493(40), 518(0.5), 713(0), 753(35), 769(0), 792(0.5), 808(0), 822(0), 846(20), 875(10), 901(0.8; br; d), 985(12), 994(12), 1023-1038(0.5; br; d), 1057(40), 1076(4; d), 1085(5), 1095(0.5), 1140(6), 1162(25), 1196(0), 1227(15), 1255(35), 1267(1), 1279(0.5), 1347(7), 1359(20), 1443(30; br), 1460(3).

It follows from the spectrum that the reaction product of this experiment consists of approximately 93-94% trans-decahydronaphthalene and 6-7% unchanged spiro-(4,5)-decane.

Experiment V. When spiro-(4,5)-decane was heated with aluminum chloride at 100°, a mixture of hydrocarbons boiling over a wide range (Table 1) was obtained. It follows from the analysis data for each fraction that they are all products of the isomerization of spiro-(4,5)-decane:

1st fraction. Found %: C 86.72; H 13.24.
2nd fraction. Found %: C 86.89; H 13.18.
3rd fraction. Found %: C 87.10; H 13.11.
4th fraction. Found %: C 86.75; H 13.18.
5th fraction. Found %: C 86.85; H 13.23. $C_{10}H_{18}$. Calculated %: C 86.87; H 13.13.

From the constants of the first fraction (Table 1) we may deduce the presence in this fraction of 2,2'-dimethyldicyclo-(0,3,3)-octane. It is known [9] that the dicyclo-(0,3,3)-octane system, unlike spiro-(4,5)-decane and decahydronaphthalene, does not change under the conditions of dehydrogenative catalysis. We therefore dehydrogenated only the 1st and 2nd fractions (the presence in the latter of a small amount of 2,2'-dimethyldicyclo-(0,3,3)-octane may be deduced from its constants). The reaction was carried out at 300-310° in a weak current of hydrogen over platinized charcoal containing 2% iron [10]. When the 1st and 2nd fractions had been passed 3 times over the catalyst, naphthalene was isolated in the mixture with the liquid hydrocarbons. When the naphthalene had been removed by freezing, a liquid fraction which could not be dehydrogenated was left, but this was not further studied in view of the small amount available.

The spectra of the first three fractions contain, in addition to the trans-decahydronaphthalene lines, a line at 576 cm^{-1} whose intensity falls from the 1st to the 3rd fraction. In the 4th and 5th fractions it becomes hardly noticeable. These fractions consist of almost pure trans-decahydronaphthalene. The total amount of trans-decahydronaphthalene formed in the conditions of this experiment exceeds 32%. The 576 cm^{-1} cannot be part of one of the spectra of the spectra of the known hydrocarbons of composition $C_{10}H_{18}$. It is possible that it is one of the characteristic lines of 2,2'-dimethyldicyclo-(0,3,3)-octane, whose spectrum is unknown.

SUMMARY

1. Trans-decahydronaphthalene is a product of the isomerization of spiro-(4,5)-decane under the influence of aluminum chloride.

2. The optimum temperature for the reaction must be taken as 75°, at which the yield of decahydronaphthalene is 93-94%. Increase in the temperature leads to the formation of products of further isomerization.

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TRANSFORMATIONS OF α-OXIDES

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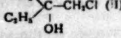
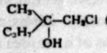
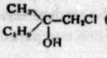
Investigations of the properties of α-oxides assume theoretical interest in recent years, since they deal with the problems of synthesizing epoxide resins, obtained from compounds containing α-oxide groups [1, 2].

The first to consider the activity of compounds containing oxide groups was Wurtz [3], who obtained glycol by the reaction of ethylene oxide with water. Later Eltekov [4] established that the rate for the reaction of α-oxides with water depends to a much greater degree on the molecular structure than on the molecular weight of the oxide. He observed an especially high reactivity with water for the unsymmetrical α-oxides. In studying the reaction of α-oxides with water Krasussky [5] observed that formation of the hydroxyl group proceeds predominantly at the least hydrogenated carbon atom and that the presence of a primary carbon oxide enhances the intensity of reaction.

The question of the influence of catalysts on the addition of alcohols to α-oxides is covered adequately in the literature. Wurtz [6] established that α-oxides react with alcohols at a much slower rate than with water. The reaction usually proceeds at elevated temperature and in the presence of catalysts. The reaction products are the monoalkyl ethers of glycols. The first-formed monoethyl ether of the glycol reacts further with additional molecules of the oxide, and here polyethylene glycol ethers of variable complexity are formed. The catalysts for this reaction are acids, boron trifluoride, alcoholates, hydrosilicates, etc. In the case of unsymmetrical α-oxides the addition of the alcohols depends on the catalyst taken. As A. A. Petrov observed [7], in the presence of alcoholates the compounds predominantly formed are the monoethers with either a secondary or tertiary alcohol group. When acid catalysts are used the primary alcohol group is formed. We failed to find any data in the literature on the influence of the molecular weight of α-oxides on the intensity of their reaction with alcohols, for which reason we directed our efforts in the present paper to a study of the influence of the molecular weight of α-oxides on their reaction with an acetylating solution and with ethyl alcohol in the presence of sulfuric acid as catalyst.

TABLE 1

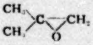
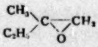
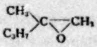
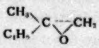
Constants of Synthesized Chloroalcohols

Name	Formula	Boiling point	d_4^{20}	n_D^{20}	MR_D found	MR_D calc.	Yield (in %)
2-Methyl-2-ol-1-chloropropane	 $(CH_3)_2C(OH){-}CH_2Cl$ (I)	127–129°	0.9384	1.4381	26.34	27.06	34
2-Methyl-2-ol-1-chlorobutane	 $(CH_3)(C_2H_5)C(OH){-}CH_2Cl$ (II)	149–152	1.0162	1.4469	32.22	31.67	22–41
2-Methyl-2-ol-1-chloropentane	 $(CH_3)(C_3H_7)C(OH){-}CH_2Cl$ (III)	65–67 (18–20 мм)	1.0304	1.4492	35.58	36.30	15.5–31.5
2-Methyl-2-ol-1-chlorohexane	$(CH_3)(C_4H_9)C(OH){-}CH_2Cl$ (IV)	78.5–80.5 (15 мм)	0.9929	1.4485	40.65	40.92	16.3–33.4

To elucidate the influence of the molecular weight and structure of α-oxides on their degree of reactivity with ethyl alcohol we synthesized the simpler α-oxides from the corresponding chloroalcohols (Tables 1 and 2).

TABLE 2

Constants of Synthesized Chloroalcohols

Name	Formula	Boiling point	d_4^{20}	n_D^{20}	MR_D		Yield (in %)
					found	calculated	
2-Methyl-1,2-epoxypropane	 (I)	50—55°	0.8351	1.4280	22.00	20.82	15.6
2-Methyl-1,2-epoxybutane	 (II)	79—83	0.8208	1.3921	24.77	25.32	14.8—23.5
2-Methyl-1,2-epoxypentane	 (III)	103—107	0.8021	1.3979 (24°)	30.07	29.93	27—43.9
2-Methyl-1,2-epoxyhexane	 (IV)	111—113	0.8019	1.4068	35.15	34.55	17.7—48.7

Chloroalcohols and α-oxides (I) and (II) are described in the literature [8]. We were unable to find a description of chloroalcohols and α-oxides (III) and (IV) in the literature. We synthesized the chloroalcohols and α-oxides by the method developed earlier by one of us [9].

The treatment of the α-oxides with an acetylating solution gave results testifying to the fact that the higher the molecular weight of the α-oxide, the greater the degree of cleavage of the three-membered ring contained in it, which is shown in Table 3.

TABLE 3

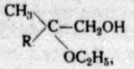
Action of Acetylation Solution on α-Oxides with Different Molecular Weights

No. of oxide	Amount of KOH (in mg)		Ring cleavage (in % of the theoretical)
	for acetic acid neutralization	theoretical	
I	268.7	777.8	35
I	270.1	777.8	
II	190.1	651.2	29
II	191.1	651.2	
III	507.2	560	94
III	549.1	560	
IV	545.0	491	100
IV	540.1	491	

The tendency for a reduction in the stability of the three-membered ring in α-oxides with increase in their molecular weight when reacted with an acetylating solution can be seen from the data in Table 3.

In studying the influence of the molecular weight of an α-oxide on the yield and formation rate of its reaction products with ethyl alcohol it was revealed that the monoethyl ethers of the glycol are obtained in good yield only from α-oxides (II) and (IV), while for the reaction of α-oxides (I) and (III) the formation of polymers of the starting α-oxides was observed. As a result, for the studied series of disubstituted unsymmetrical α-oxides a lesser influence of the molecular weight is observed when compared with the influence of their substituents on the transformations under the indicated conditions.

The formation of polymers can be explained by the transformation of α-oxides, evoked by the tendency to polymerize shown by compounds containing in their composition, besides the methyl group, substituents with an odd number of carbon atoms. In the case of the presence in α-oxides of substituents with an even number of carbon atoms, the monoethers of the corresponding glycols of type



$$\begin{matrix} CH_3 \\ R \end{matrix}\!\!>\!C{-}CH_2OH \quad (OC_2H_5),$$

are formed, where R corresponds to the alkyl radical of the starting α-oxide.

EXPERIMENTAL

Synthesis of 2-methyl-2-ol-1-chloropropane. The compound was prepared through the organomagnesium compound from chloroacetone and methyl iodide. The chloroacetone was prepared by the method described by Fritsch [10] (b.p. 118-120°, d_4^{20} 1.1445). The methyl iodide used had b.p. 43° and d_4^{20} 2.219, which are in agreement with the literature data [11]. To 36 g of magnesium with stirring and cooling was added 110 g of methyl iodide in 200 ml of diethyl ether. At the end of 20 hours the reaction mixture was treated under cooling with 62 g of chloroacetone in 200 ml of ether. After 48 hours water was added to the flask with cooling and stirring until all of the organomagnesium complex had decomposed. The yield of the chloroalcohol and its constants are given in Table 1. The constants agree with the literature data [8].

Synthesis of 2-methyl-1,2-epoxypropane. To a solution of 24 g of the chloroalcohol in 100 ml of ether was added in portions 22 g of powdered potassium hydroxide. The yield of the obtained oxide and its constants, showing agreement with the literature data [8], are given in Table 2.

Synthesis of 2-methyl-2-ol-1-chlorobutane. This compound was synthesized from chloroacetone and ethyl bromide (with b.p. 38-38.4° and d_4^{20} 1.4564) under conditions similar to those used to obtain the above described chloroalcohol. The yield and constants are given in Table 1. The constants correspond to the literature data [8].

The synthesis of 2-methyl-1,2-epoxybutane was accomplished by the above indicated method. The yield and constants of the oxide (Table 2) corresponds with the literature data [8].

Synthesis of 2-methyl-2-ol-4-chloropentane. Since we were unable to find any data in the literature on the synthesis of chloroalcohols (III) and (IV), the conditions used to prepare them are described in detail. To 51 g of magnesium with cooling and stirring was added 225 g of propyl bromide (b.p. 71-71.5°, d_4^{20} 1.3515), dissolved in 500 ml of ether. After 20 hours to the reaction mixture with cooling and stirring was added in drops 150 g of chloroacetone, dissolved in 500 ml of ether. After 48 hours the formed organomagnesium complex was decomposed with water and the chloroalcohol extracted with ether. After drying the ether solution over sodium sulfate and distilling off the ether we obtained 176 g of product, which was distilled in vacuo at 25 mm. Three fractions were obtained: 1st 40-50°, 4 g; 2nd 52-55°, 6.5 g; 3rd 56-70°, 70 g (31.5%); residue 41 g. Redistillation of the 3rd fraction gave 34.5 g (15.5%) of the chloroalcohol—a colorless liquid, darkening on standing, with b.p. 66-67° (18-20 mm), the constants of which are given in Table 1.

Found %: C 52.93, 52.45; H 8.76, 9.64; Cl 26.22, 25.56. M 137, 136. $C_6H_{13}OCl$. Calculated %: C 52.71; H 9.52; Cl 25.98. M 136.6.

Additional proof for the structure of this chloroalcohol is the synthesis of the corresponding α-oxide from it.

Synthesis of 2-methyl-1,2-epoxypentane. To a solution of 73 g of the chloroalcohol in 200 ml of ether was added in portions 146 g of powdered potassium hydroxide. After removal of the inorganic compounds and distillation of the ether we obtained 29 g (54.2%) of product, distilling at 100-107°. Redistillation gave 24 g (43.9%) of the oxide with b.p. 103-107°. The oxide was a colorless liquid with an ether odor.

Found %: C 71.76, 71.96; H 12.08, 11.78. M 101.8, 100.1. $C_6H_{12}O$. Calculated %: C 71.93; H 12.09. M 100.1.

Synthesis of 2-methyl-2-ol-1-chlorohexane. To 59 g of magnesium in a round-bottomed flask was added in drops with cooling and stirring 245 g of butyl bromide (b.p. 101.6°, d_4^{20} 1.2754), dissolved in 750 ml of ether. After 20 hours to the reaction mixture with cooling and stirring was added in drops 146 g of chloroacetone in 500 ml of ether, and after 48 hours the organomagnesium complex was decomposed with water and the chloroalcohol extracted with ether. After drying the ether solution and distilling off the ether was obtained 160 g of product, which distilled at 15 mm: 1st fraction 25-78.5°, 41 g; 2nd fraction 78.5-80.5°, 39 g; residue 51 g.

The 2nd fraction, corresponding to the chloroalcohol, was a colorless liquid, turning dark on standing (Table 1).

Found %: C 55.87, 55.54; H 10.00, 9.95; Cl 23.42, 23.00. M 154, 157. $C_7H_{15}OCl$. Calculated %: C 55.40; H 9.97; Cl 23.41. M. 150.62.

Synthesis of 2-methyl-1,2-epoxyhexane. To a solution of 60 g of the chloroalcohol in 600 ml of ether was added in portions 120 g of powdered potassium hydroxide. After removal of the inorganic compounds and distillation of the ether we obtained 22 g of product, the distillation of which gave three fractions: 1st 106-110°, 4 g; 2nd 111-113°, 8 g; 3rd 113-183°, 5 g; residue 5 g. The constants of the 2nd fraction of the α-oxide are given in Table 2.

Found %: C 73.41, 73.30; H 12.29, 12.29. M 117.0, 112.2. $C_7H_{14}O$. Calculated %: C 73.63; H 12.37. M 114.

Oxide (IV) is a colorless liquid with an ether odor.

All of the synthesized α-oxides were checked for the stability of their ring under the influence of acetic anhydride in pyridine solution, and also under the influence of ethyl alcohol in the presence of sulfuric acid as catalyst.

Study of the Relationship Between the Stability of the Three-Membered Ring in α-Oxides and Their Molecular Weight

The action of an acetylating solution on α-oxides was run with the solution used to determine hydroxyl numbers by the method of Verley and Bolsing, described in detail by Kaufmann [12]. Into a 150-ml flat-bottomed flask was weighed 1-1.5 g of the α-oxide, and then to the same flask was added 2 ml of the acetylation solution, composed of one volume of acetic anhydride and three volumes of pyridine. At the same time a control flask with the same amount of acetylation mixture was prepared. The flasks were fitted with air condensers, and then they were immersed in a water bath for 1 hour at 95°. After removal from the bath and cooling, to the flasks was added through the condenser along the sides a very fine stream of 0.5-1 ml distilled water, then 5 ml of neutral alcohol, and the acetic acid was titrated with 0.5 N alcoholic potassium hydroxide solution in the presence of phenolphthalein. As is known, the reaction of α-oxides with acids or their derivatives yields partial esters. This method was also used to determine the hydroxyl numbers given below. The results of treating the α-oxides with an acetylating solution are given above in Table 3.

The action of ethyl alcohol in the presence of sulfuric acid on α-oxides. To the α-oxide, contained in a round-bottomed flask, was added a known amount of ethyl alcohol (96 %) and c.p. sulfuric acid (d 1.84). After shaking the reaction mixture the flask was placed on a water bath, the temperature of which was thermostatically controlled with the aid of an electrical contact thermometer at 58 ± 1°. After heating the flask contents for 1.5 hours the reaction mixture was neutralized with potassium hydroxide, the alcohol distilled off, and the reaction product distilled. Conditions close to these were used by F. Ya. Perveev and N. I. Kudryashova [13], and also by A. A. Petrov and co-worker [1], to study the influence of catalysts on the character of the addition of alcohols to α-oxides.

The experiments with all of the α-oxides were run under similar conditions by the indicated method.

Action of ethyl alcohol on α-oxide (I). To 6.85 g of the oxide was added 99 ml of ethyl alcohol and 0.53 ml of sulfuric acid. After heating and distilling off the alcohol we obtained 2.35 g (34%) of product, free of both starting oxide and alcohol. Distillation of this product gave the following fractions: 1st, b.p. to 165°, 0.48 g, n_D^{23} 1.4245; 2nd b.p. 165-171°, 0.91 g, n_D^{23} 1.4260; residue 0.37 g, n_D^{23} 1.4351.

The elementary composition and molecular weight of the 2nd fraction indicates that the obtained substance is a mixture of the dimer and trimer of the starting α-oxide (I).

Found %: C 66.71, 66.57; H 11.53, 11.47. M 227.9, 197.6. C_4H_8O. Calculated %: C 66.66; H 11.11. M (dimer) 144; M (trimer) 216.

Action of ethyl alcohol on α-oxide (II). As the result of heating 13.55 g of the oxide, 197 ml of alcohol and 1.13 ml of sulfuric acid, and distilling off the alcohol, we obtained 10.12 g (76.8%) of product. Distillation gave the following fractions: 1st, to 166°, 4.89 g, n_D^{23} 1.4181; 2nd 166-171°, 4.35 g, n_D^{23} 1.4278; residue 0.31 g; n_D^{23} 1.4300.

The elementary composition and molecular weight of the 2nd fraction indicates that it is the monoether of the corresponding glycol.

Found %: C 62.17, 62.26; H 11.88, 11.75. M 144, 147. $C_6H_{16}O_2$. Calculated %: C 63.57; H 12.21. M 132.

In repeating the experiment the similar fraction of the monoether (V) had the following constants:

B.p. 167-170°, d_4^{20} 5.9171, n_D^{20} 1.4320.
Hydroxyl number: 411, 419. Calculated hydroxyl number for monoether (V) 424.

Action of alcohol on α-oxide (III). As the result of heating 19.24 g of the oxide, 280.6 ml of alcohol and 1.6 ml of sulfuric acid we obtained 18 g (93.5%) of product, from which by distillation we obtained the following fractions: 1st, 78-80°, 5.3 g, n_D^{24} 1.4071; 2nd 165-213°, 1.35 g, n_D^{24} 1.4288; 3rd 213-217°, 2.5 g, n_D^{24} 1.4339; residue 3.4 g, n_D^{24} 1.4500.

For the 3rd fraction (oxide III) the found % was: C 71.30, 71.27; H 11.73, 11.71. M 178.6, 185. $C_6H_{12}O$ (oxide III). Calculated %: C 71.93; H 12.09. M (dimer) 200.

The double molecular weight can be explained by the formation of the dimer of the α-oxide under these conditions.

Action of ethyl alcohol on oxide (IV). From 14.77 g of the oxide, 207 ml of alcohol and 1.23 ml of sulfuric acid we obtained 8.05 g (55.2%) of product. Distillation at atmospheric pressure gave from 3.7 g the following fractions: 1st 92-186°, 0.65 g, n_D^{23} 1.4330; 2nd 186-187°, 0.43 g, n_D^{23} 1.4389; 3rd 187-250°, 1.14 g, n_D^{23} 1.4280. In view of the fact that this reaction product decomposed when distilled at atmospheric pressure, it was vacuum-distilled at 20 mm; from 4.35 g we obtained two fractions: 1st 43-67°, 1.84 g, n_D^{23} 1.4330; 2nd 67-69°, 0.51 g, n_D^{23} 1.4330.

For the 2nd fraction (monoether V) the found %: C 67.82, 67.92; H 12.33, 12.36. M 166.2, 174; hydroxyl number 257. $C_9H_{20}O_2$. Calculated %: C 67.43; H 12.59. M 160; hydroxyl number 350.

The hydroxyl number, the same as the molecular weight, can indicate that a certain amount of the α-oxide dimer is also present in the monoether.

SUMMARY

1. In this paper we synthesized and characterized two new chloroalcohols: 2-methyl-2-ol-1-chloropentane and 2-methyl-2-ol-1-chlorohexane, and the two α-oxides corresponding to them.

2. When α-oxides are treated with an acetylation solution a tendency is observed for the three-membered ring to decrease in stability as the molecular weight of the α-oxide is increased. This same tendency is also observed for the studied series of α-oxides when they are treated with ethyl alcohol in the presence of sulfuric acid.

3. The action of ethyl alcohol in the presence of sulfuric acid on α-oxides leads either to their polymerization with the formation of dimers and trimers or to the formation of the monoethers of the glycols.

4. The formation of polymers can be explained by the transformation of α-oxides, evoked by the special tendency shown by these compounds to polymerize.

5. The direction of the reaction of α-oxides with ethyl alcohol depends to a greater degree on the structure of their substituents than on their molecular weight, since when a substituent with an even number of carbon atoms is present in the α-oxide molecule the reaction proceeds with the formation of the corresponding glycol monoether, while in the presence of a substituent with an odd number of carbon atoms the reaction proceeds in the direction of forming polymers of the type of full ethers of the corresponding glycols.

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SYNTHESIS OF 7,8-DIMETHYLTETRADECANE

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Among the components of diesel and reaction fuel 7,8-dimethyltetradecane deserves consideration, a method for the synthesis of which has not yet been adequately developed, while the existing data on its physicochemical properties, due to contamination by secondary products of the synthesis, cannot be fully reliable.

Alekhin [1] accomplished the synthesis of this hydrocarbon by reacting 2-bromooctane with sodium in xylene medium. Lachowicz [2] ran this reaction in benzene medium. Both authors mentioned the very substantial formation of secondary reaction products—low-boiling unsaturated hydrocarbons and high-boiling compounds. A. A. Zepalova-Mikhailova [3] ran the synthesis of 7,8-dimethyltetradecane by reacting 2-bromooctane with sodium in absolute ether medium. The synthesis products were also strongly contaminated by unsaturated compounds, after the removal of which the yield of the hydrocarbon was about 20% (calculated by us). A. D. Petrov and E. P. Kaplan [4] describe the synthesis of 7,8-dimethyltetradecane, running the reaction in xylene medium by the A. Alekhin method. However the authors, giving a 16.5% yield of the hydrocarbon, do not indicate on what it was based (2-bromooctane was obtained from methyl hexyl ketone through 2-octanol). Lane and Ulrich [5] obtained 7,8-dimethyltetradecane from 2-chlorooctane in pentane medium with the addition of ethyl acetate; here the yields were 36% of octane, 38% of octenes and 16% of 7,8-dimethyltetradecane. When the reaction with 2-bromooctane was run in pentane medium with the addition of methyl cyanide the yield of the hydrocarbon was 11% (it is not clear on what the yields of the synthesis products are based).

The purpose in the present study was to find the most favorable conditions for the synthesis of 7,8-dimethyltetradecane, assuring a quite high and stable yield, and also a pure product. As solvents for the reaction we used o-xylene, isooctane, dibutyl and diethyl ethers, and the dearomatized fraction of direct-distillation benzine. In studying the influence of the reaction medium on the character of the reaction of 2-bromooctane with sodium we noted a number of interesting traits, associated with the mechanism of the Wurtz reaction. It was established that the main condition for the successful synthesis of 7,8-dimethyltetradecane from 2-bromooctane is the presence of a polar solvent with a sufficiently high boiling point, such as, for example, xylene and dibutyl ether. However, under the synthesis conditions xylene suffers profound alkylation by the alkyl bromide, which determines the substantial yield of high-boiling aromatic products that is obtained here, contaminating the desired synthesis product; consequently, xylene is not suitable as a solvent for this reaction. The best medium is dibutyl ether (Table 1). When the reaction is run in this solvent there is hardly any formation of the low-boiling octane-octene fraction with b.p. 110-130°, the presence of which was mentioned by all of the other investigators who studied this reaction in other solvents as the medium [1,3,5]. The formation of this fraction among the reaction products was also observed by us when we used dearomatized benzine, isooctane or diethyl ether as the reaction medium (Table 2).

The absence of octane and octenes in the products of the reaction, run in dibutyl ether medium, indicates that the latter does not react with a sodium alkyl, as could have been expected in accord with the reaction established by P. P. Shorygin [6]:

$$C_2H_5Na + (C_2H_5)_2O \rightarrow C_2H_5ONa + C_2H_4 + C_2H_6.$$

The yield of 7,8-dimethyltetradecane under the optimum conditions of running the synthesis is 60-70% on the liquid synthesis product, and 30% when calculated on the 2-bromooctane. Taking into consideration the diffulty with which secondary bromides react in the sense of the Wurtz reaction [7,8], such a yield of the hydrocarbon

TABLE 1

Expt. Nos.	Solvent	Reaction temperature	Time (in hours)	Yield 7,8-dimethyltetradecane
1	o-Xylene	144°	3	15
5	Isooctane	99	3	None
9	Benzine	130—150	4	None
3	Dibutyl ether	140—142	3	37
4	Dibutyl ether	140—142	4	30
7	Dibutyl ether	140—142	4	27
8	Diethyl ether	34—35	5	19

TABLE 2

Expt. Nos.	110-130° (756 mm) octene-octane fraction		Up to 100° (20 mm) 2-bromooctane		100-135° (20 mm)		135-160° (20 mm) 7,8-dimethyltetradecane		Residue	Losses
	(wt. %)	unsaturates (in %)	(wt. %)	n_D^{20}	(wt. %)	n_D^{20}	(wt. %)	n_D^{20}	(wt. %)	(wt. %)
5	39.7	16.0	54.0	1.4440	—	—	—	—	2.8	3.5
9	26.7	27.8	57.4	1.4420	—	—	—	—	12.7	3.2
3	—	—	22.2 *	1.4030	—	—	61.2	1.4381	13.8	2.8
4	—	—	6.2 *	1.4025	3	1.4300	73.5	1.4382	14.4	2.9
7	—	—	22.0 *	1.4028	—	—	61.5	1.4384	15.7	0.8
8	51.0	51.3	10.5	1.4393	10	1.4425	27.4	1.4385	1.1	0

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* The fraction up to 100° (20 mm) represents dibutyl ether with a small amount of 2-bromooctane as impurity.

can be considered as being quite good. Of the secondary reactions prevailing under the synthesis conditions, only the polymerization processes play a significant role, leading to the formation of a heavy residue from the distillation (13-15% on the liquid synthesis product).

It was shown that a reduction in the reaction temperature (when the synthesis is run in absolute diethyl ether medium) leads to a reduction in the degree of 2-bromooctane conversion to the hydrocarbon, and to an increase in the role played by the secondary reactions of hydrogen disproportionation, determining the formation of octane and octenes [7,8]: $C_8H_{17}Br + C_8H_{17}Na \rightarrow C_8H_{18} + C_8H_{16} + NaBr$ and $2C_8H_{17}Na \rightarrow C_8H_{16} + C_8H_{18} + 2Na$.

The yield of 7,8-dimethyltetradecane in this case does not exceed 19%; heavy products, boiling at a higher temperature than the 7,8-dimethyltetradecane, are not formed.

On the basis of the obtained data it can be assumed that in polar solvents at low temperatures the condensation of alkyls and the disproportionation of hydrogen proceed sinultaneously at commensurate rates. The temperature coefficient for the rate of the first reaction is considerably higher than for the second reaction; consequently, at a higher temperature of about 140°, in dibutyl ether medium, only the reaction with the formation of 7,8-dimethyltetradecane proceeds for all practical purposes. A similar influence of the temperature on the progress of the hydrogen disproportionation reaction was also observed by us in the nonpolar solvents: isooctane (b.p. 99°) and benzine (130-150°), where this reaction was mainly directed toward the conversion of the 2-bromooctane (Table 2).

It should be mentioned that there fail to be any definite statements in the literature on the significance of the polarity of the solvent used in running the synthesis of hydrocarbons by the Wurtz reaction. Meanwhile, this factor is a decisive one for the synthesis of 7,8-dimethyltetradecane, as can be seen when the results of the experiments run in dibutyl ether medium and in the dearomatized benzine fraction are compared. Despite the practically same reaction temperature (~140°) in both cases, in the benzine medium we were completely unable to obtain 7,8-dimethyltetradecane, and more than 50% of the 2-bromooctane remained unchanged.

In the light of the data obtained by us the reason for the favorable influence exerted by the addition of various polar substances, for example methyl cyanide or ethyl acetate, on the synthesis of hydrocarbons by the Wurtz reaction, accomplished in nonpolar solvents, becomes clear [5].

EXPERIMENTAL

Starting substances for the synthesis of 7,8-dimethyltetradecane. 2-Octanol–commercial product; b.p. 179-180°, n_D^{20} 1.4246, d_4^{20} 0.822; 48% hydrobromic acid was obtained by the method of [9], the reaction of sulfur dioxide with bromine in the presence of water. Yield 90%. 2-Bromooctane was synthesized by a modification of our method given in [10]. The bromination of 2-octanol was run with a mixture of hydrobromic and sulfuric acids, with heating on the boiling water bath for 7 hours. We took 3 moles of HBr and 0.75 mole of H_2SO_4 (d 1.84) for 1 mole of the alcohol. Yield of 2-bromooctane 58%, b.p. 187-188°, n_D^{20} 1.4510, d_4^{20} 1.1010. From [11]: b.p. 188°, n_D^{20} 1.4510, d_4^{20} 1.099.

The solvents, used for the synthesis of the hydrocarbon by the Wurtz reaction, were first dried over calcium chloride, boiled over metallic sodium for 3 hours, and then distilled from a flask fitted with dephlegmator.

o-Xylene, b.p. 144°, n_D^{20} 1.5050, d_4^{20} 0.8810; isooctane (2,2,4-trimethylpentane), b.p. 98.5-99.0°; n_D^{20} 1.3928, d_4^{20} 0.6922; dibutyl ether, b.p. 141-142°, n_D^{20} 1.3992, d_4^{20} 0.769; diethyl ether, b.p. 34-35°, n_D^{20} 1.3497, d_4^{20} 0.708; the direct-distillation dearomatized benzine boiled in the range 130-150°, and was obtained by the fractional distillation of gas-condensate benzine with subsequent removal of the aromatic compounds on silica gel.

7,8-Dimethyltetradecane was synthesized by the Wurtz reaction from 2-bromooctane and sodium in a solvent medium. For 1 g of the 2-bromooctane we took 0.36 g of sodium, which corresponds to a 3-fold excess when compared with the amount required by the stoichiometric equation. The reaction was run in a round-bottomed flask, fitted with a mechanical stirrer, dropping funnel and reflux condenser. The solvent, taken in the ratio of 0.75 volume per volume of 2-bromooctane, and the necessary amount of finely-cut sodium were charged into the flask. The 2-bromooctane was slowly added to the solvent, heated to the boil, with vigorous stirring of the mixture. When all the bromide had been added the reaction mixture was held at the boiling point of the solvent for 3-4 hours. After cooling the reaction mixture, the precipitate of sodium bromide together with unreacted metallic sodium was separated and washed 4 times with hot solvent. The obtained filtrate was distilled. Using a flask fitted with a dephlegmator, the solvent and the fraction with b.p. 110-130°, representing a mixture of octane with octenes, were removed by atmospheric distillation. Further distillation was made at 20 mm. Unreacted 2-bromooctane was collected up to 100°, from 100 to 135°–an intermediate fraction, while the 7,8-dimethyltetradecane was collected in the range 135-160°. As a rule, the main portion (about 95%) of the hydrocarbon distilled at 145-149° (20 mm), and 265-272° (760 mm). A residue remained in the flask after distillation, representing a complex mixture of secondary reaction products. The conditions used and the experimental results are summarized in Table 1, while the distillation results for the synthesis products are given in Table 2.

For the purpose of obtaining a purer hydrocarbon the residue from Expt. 4, obtained after distilling off the solvent from the synthesis products, was subjected to a vacuum-rectification through a column with an efficiency of 10 theoretical plates. The physicochemical constants of a one-degree fraction with b.p. 148° at 20 mm are given in Table 3, and for comparison, also the data obtained by other investigators for 7,8-dimethyltetradecane. Without doubt the constants for 7,8-dimethyltetradecane, indicated in the paper of Petrov and Kaplan [4] and entering into the handbook literature [12], are somewhat high, due to contamination of their obtained hydrocarbon by aromatic compounds.

TABLE 3

Boiling point at 760 mm	n_D^{20}	d_4^{20}	Freezing point
270° (obtained by us)	1.4382	0.7835	—86°
267.5—269.5 [1]	—	0.7923 (14°)	below —30
263—265 [2]	—	0.8011 (18°)	—
270 [3]	1.4373	0.7807	—
268—270 [4]	1.4430	0.7921	—70
258—262(767) [5]	1.4373	—	—
258—268(764) [5]	1.4383	—	—

SUMMARY

1. The influence of the reaction medium on the synthesis of 7,8-dimethyltetradecane by the Wurtz reaction was studied. It was shown that the latter is formed in substantial amounts only in polar solvents.

2. It was established that the best reaction medium for running the reaction of 2-bromooctane with sodium is dibutyl ether. The average yield of 7,8-dimethyltetradecane in this case is 30%.

3. The physicochemical constants of 7,8-dimethyltetradecane were determined and made more accurate.

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THE ORGANOMAGNESIUM SYNTHESIS AND HYDROGENATION OF TRIPHENYLALKYLMETHANES

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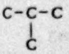
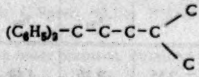
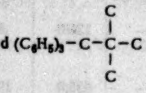
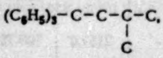
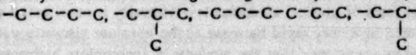
The synthesis of homologs of triphenylmethane was begun some 50 years ago by the study of Gomberg and Cone [1], who obtained by the Grignard reaction: $(C_6H_5)_3-C-C-C$ (I), $(C_6H_5)_3-C-C-C-C$ (II),  $(C_6H_5)_3-C-\underset{\substack{|\\C}}{C}-C$ (III),  $(C_6H_5)_3-C-C-C-C{<}^{C}_{C}$ (IV). Of the properties of these hydrocarbons the authors gave only the boiling point and the melting point. The latter, due to the small amounts of hydrocarbons synthesized, were not always determined accurately. For example, a m.p. of +79° was given for hydrocarbon (II), while the isomeric hydrocarbon (III) proved to be a liquid. Actually, the difference in the melting points can hardly be so great. The later synthesized  $(C_6H_5)_3-C-\overset{\substack{C\\|}}{\underset{\substack{|\\C}}{C}}-C$ has m.p. 185° [2], $(C_6H_5)_3-C-C-C-C-C$, obtained through Li-butyl has m.p. 153° and finally  $(C_6H_5)_3-C-C-\underset{\substack{|\\C}}{C}-C$, obtained by us in the present study, has m.p. 148°.

Of the hydrocarbons in this series only triphenylmethane has been subjected to both incomplete and complete hydrogenation; in this connection it was established that the fully hydrogenated product $(C_6H_{11})_3CH$, according to some data, has m.p. 47.5-48.5° [4], and according to other data, a m.p. of +61° [5]. This difference in the melting point can be explained, not by the fact that the first investigators had an impure product, but by a different ratio of the stereoisomeric forms (reverse isomers), obtained under the hydrogenation conditions. The incomplete hydrogenation product–dicyclohexylphenylmethane–a liquid with b.p. 196-197° at 17 mm, was first obtained by Godchot [6].

Within the scope of the present study we included the organomagnesium synthesis of hydrocarbons of the $(C_6H_5)_3CR$ series, where R is equal to  $-C-C-C-C$, $-C-\underset{\substack{|\\C}}{C}-C$, $-C-C-C-C-C-C$, $-C-\underset{\substack{|\\C}}{C}-C_4$. As we had expected, the melting point decreased with increase in the length of R, and in the last cast it dropped to room temperature, and here it could not be determined accurately, in view of the fact that the product congealed to a glass (Table 1). With increase in the chain length the yields also decreased from 50% for the first two members of the series to 7% for the last member of the series.

Hydrogenation over Bag catalyst [7] at 270-280° and over Raney nickel [8] at 100° led only to the formation of dicyclohexylphenylalkylmethanes. Only on Raney nickel at 140° and a pressure of 150 atm. (under these conditions only the second and third members of the indicated series underwent hydrogenation) were we able to obtain the tricyclohexylalkylmethanes. It should be mentioned that, together with the formation of the latter, there also occurred partial cracking with the cleavage of either cyclohexyl (and the formation of dicyclohexylalkylalkanes) or of the alkyl chain [and the formation of $(C_6H_{11})_3CH$]

Since both the incomplete and complete hydrogenation products, and also the dicyclohexylmethanes, proved to be liquids, this made it possible for us to determine their viscosity at various temperatures. The viscosity values in centipoises and the freezing points of the obtained cyclic hydrocarbons are presented in Table 2.

TABLE 1

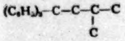
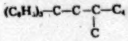
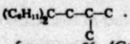
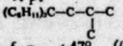
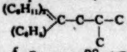
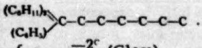
Substance	Melting point
$(C_6H_5)_3-C-C-C-C-C$	153—154° (Crystals)
 $(C_6H_5)_3-C-C-\underset{\mid \atop C}{C}-C$	148—149 (Glass)
$(C_6H_5)_3-C-C-C-C-C-C-C$	76—76.5 (Crystals)
 $(C_6H_5)_3-C-C-\underset{\mid \atop C}{C}-C_4$	$<$25—30 (Glass)

TABLE 2

Expt. Nos.	Hydrocarbons	ν_0	ν_{20}	ν_{50}	ν_{100}	ν_{150}
1	 $(C_6H_{11})_2C-C-\underset{\mid \atop C}{C}-C$ .... f.p. +8° (Crystalline)	—	34.7	7.55	2.16	1.44
2	$(C_6H_{11})_2C-C-C-C-C-C-C$ .... f. p. —35° (Glass)	208.35	39.30	7.90	2.02	—
3	 $(C_6H_{11})_3C-C-\underset{\mid \atop C}{C}-C$ .... f. p. +47° (Crystalline)	—	—	126.0	8.14	—
4	$(C_6H_{11})_3C-C-C-C-C-C-C$ .... f. p. +9° (Glass)	—	—	635.0	19.40	3.22
5	 $\left.\begin{matrix}(C_6H_{11})_2\\(C_6H_5)\end{matrix}\right\rangle C-C-\underset{\mid \atop C}{C}-C$ .... f. p. —2° (Glass)	—	2157.0	100.72	8.05	1.87
6	 $\left.\begin{matrix}(C_6H_{11})_2\\(C_6H_5)\end{matrix}\right\rangle C-C-C-C-C-C-C$ ... f. p. —2° (Glass)	—	11794.0	229.7	8.1	—

We see that the temperature curves for the viscosity of the crystalline forms, even at temperatures close to the crystallization point, are characterized by quite a gentle slope. In the case of the forms, losing their mobility when in the form of glasses, an anomalous viscosity is manifested even long before their vitrification temperatures, expressed in a very rapid increase of the absolute viscosity value and in a deterioration of the index. It should also be mentioned that the products of incomplete hydrogenation (dicyclohexylphenylalkylmethanes) are characterized by lower freezing points when compared with the products of complete hydrogenation (tricyclohexylalkylmethanes) and even a somewhat more sloping temperature curve of the viscosity.

EXPERIMENTAL

1,1,1-Triphenylpentane. Synthesized from triphenylchloromethane [9] and n-C_4H_9MgBr. Viscous product with b.p. 195-198° at 3 mm. Yield 50%. On standing it congealed to give crystals with m.p. 150°.

Found %: C 91.65, 91.45; H 7.26, 7.24. $C_{23}H_{24}$. Calculated %: C 91.94; H 8.06.

The literature [3] gives a m.p. of 153° and a yield (in the synthesis through LiC_4H_9) of 26%.

1,1-Dicyclohexyl-1-phenylpentane had the following properties: b.p. 167-170° at 3 mm, n_D^{40} 1.5390, d_4^{40} 0.9700. The hydrocarbon loses its mobility, congealing to a glass at 0-2°.

Found %: C 89.30, 89.28; H 10.84. $C_{23}H_{36}$. Calculated %: C 88.74; H 11.56.

1,1,1-Triphenyl-3-methylbutane was obtained under similar conditions in an amount exceeding 100 g, b.p. 195-198° (3 mm), m.p. 148-149°.

Found %: C 91.13, 91.05; H 7.86, 7.94. $C_{23}H_{24}$. Calculated %: C 91.94; H 8.06.

The incomplete hydride—1,1-dicyclohexyl-1-phenyl-3-methylbutane—had the following properties:

B.p. 162-165° at 3 mm, n_D^{40} 1.5370, d_4^{40} 0.9714; f.p. -2° (glass).
Found %: C 88.74, 88.96; H 11.34, 11.52. $C_{23}H_{36}$. Calculated %: C 88.44; H 11.56.

The complete hydrogenation product—1,1,1-tricyclohexyl-3-methylbutane, obtained in a 100 g amount, after distillation over sodium and fractionation through a column with an efficiency of 18 theoretical plates, had the following properties:

B.p. 168-170° at 3 mm, m.p. 47°, n_D^{50} 1.4952, d_4^{50} 0.9195.
Found %: C 86.45, 86.51; H 13.13, 13.25. $C_{23}H_{42}$. Calculated %: C 86.70; H 13.30.

From the lower fraction, obtained in 15% yield, we isolated 1,1-dicyclohexyl-3-methylbutane with the following properties:

B.p. 130-132° at 3 mm, f.p. +8° (crystal), n_D^{20} 1.4790, d_4^{20} 0.8885.
Found %: C 86.28, 86.38; H 13.52, 13.48. $C_{17}H_{32}$. Calculated %: C 86.34; H 13.65.

Sabatier and Murat [10], the first to synthesize this hydrocarbon, give for it b.p. 290-291°, d_0^{21} 0.8940, n_D^{21} 1.489.

1,1,1-Triphenylheptane was obtained under similar conditions in a 120 g amount or a 35% yield. B.p. 182-183° at 3 mm.

Found %: C 91.66, 91.61; H 8.46, 8.47. $C_{25}H_{28}$. Calculated %: C 91.42; H 8.58.

On Raney nickel at 100° and 150 atm. of pressure we obtained 1,1-dicyclohexyl-1-phenylheptane with b.p. 165-167° at 3 mm, f.p. -2° (glass), n_D^{40} 1.5200, d_4^{40} 0.9458.

Found %: C 87.97, 88.05; H 11.84, 11.85. $C_{25}H_{40}$. Calculated %: C 88.15; H 11.85.

Under the same conditions, but at 140°, we obtained 1,1,1-tricyclohexylheptane, b.p. 202-203° at 4 mm, f.p. +9° (glass), n_D^{40} 1.5105, d_4^{40} 0.9344.

Found %: C 87.14, 87.04; H 12.82, 12.84. $C_{25}H_{46}$. Calculated %: C 86.61; H 13.39.

Fractionation of the low-boiling hydrogenation fraction through a column with an efficiency of 18 theoretical plates gave two fractions:

1st b.p. 155° at 5 mm, m.p. +45°, n_D^{50} 1.5020, d_4^{50} 0.9227.

Found %: C 86.71, 86.85; H 13.02, 13.05. $(C_6H_{11})_3CH$. Calculated %: C 86.93; H 13.07.

Literature [4] gives for $(C_6H_{11})_3CH$, m.p. 47.5-48.5°, n_D^{50} 1.4967, d_0^{40} 0.9265.
2nd fraction, b.p. 190° at 5 mm, f.p. -35° (glass), n_D^{20} 1.4840, d_4^{20} 0.8930.

Found %: C 86.50, 86.70; H 13.49, 13.39. $(C_6H_{11})_2CH(CH_2)_5CH_3$. Calculated %: C 86.27; H 13.73.

1,1,1-Triphenyl-3-ethylheptane was obtained in 18 g amount.

B.p. 210-212° at 4 mm, n_D^{40} 1.5730, d_4^{40} 1.005, f.p. <20° (glass).
Found %: C 90.32, 90.48; H 8.59, 8.61. $C_{27}H_{32}$. Calculated %: C 90.94; H 9.06.

Hydrogenation over Raney Ni gave 1,1-dicyclohexyl-1-phenyl-3-ethylheptane.

B.p. 196-198° at 4 mm, f.p. 0° (glass), n_D^{40} 1.5175, d_4^{40} 0.9463.
Found %: C 88.50, 88.63; H 11.72, 11.55. $C_{27}H_{44}$. Calculated %: C 87.96; H 12.04.

SUMMARY

1. We synthesized for the first time: 1,1,1-triphenyl-3-methylbutane, 1,1,1-triphenylheptane, 1,1,1-triphenyl-3-ethylheptane, 1,1-dicyclohexyl-1-phenylbutane, 1,1-dicyclohexyl-1-phenyl-3-methylbutane, 1,1-dicyclohexyl-1-phenylheptane, 1,1-dicyclohexyl-1-phenyl-3-ethylheptane, 1,1,1-tricyclohexyl-3-methylbutane, 1,1,1-tricyclohexylheptane and 1,1-dicyclohexylheptane.

2. It was established in the series of incomplete and complete hydrides of the triphenylalkylmethanes studied by us that the melting points and freezing points decrease with increase in the length of the alkyl radicals, and at the same time there arises a tendency for the crystalline forms to migrate into glasses.

3. Whereas the temperature curves for the viscosity of the crystalline forms, even at temperatures close to the crystallization point, are characterized by quite a gentle slope, in the case of the forms, losing their mobility in the form of glasses, even long before the vitrification temperatures an anomalous viscosity is observed, expressed in a very rapid rise of the absolute viscosity value and in a deterioration of the index.

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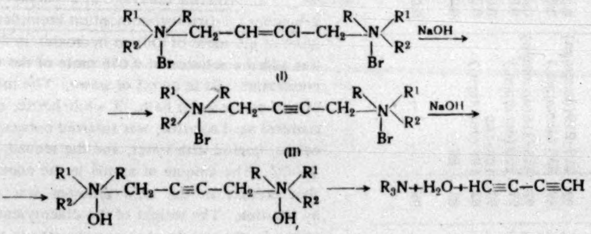
QUATERNARY AMMONIUM COMPOUNDS

VI. CLEAVAGE OF 2-BUTYNE- and 2-CHLORO-2-BUTENE-1,4-DI-(TRIALKYLAMMONIUM BROMIDES) WITH AQUEOUS ALKALI

A. T. Babayan, G. M. Mkryan and Sh. L. Mndzhoyan

Earlier on the example of the ethers of 2-butyn-1-ol [1] and of quaternary ammonium salts, containing the 2-butynyl radical [2], the possibility of 1,4-cleavage with the formation of vinylacetylene was shown. It is also known that the treatment of 1,4-dichloro-2-butyne with zinc dust yields butatriene [3], while when heated with alkali it loses two molecules of hydrogen chloride with the formation of diacetylene [4]. One of us [2] had shown that quaternary ammonium salts, containing the 3-chloro-2-butenyl radical, when heated with aqueous alkali, together with the normal products of 1,4-cleavage, also form dehydrochlorination-cleavage products–vinylacetylene.

All of the above gave basis to assume that 1,4-diquaternary ammonium salts of 2-butyne of general formula (II) and of 2-chloro-2-butene of general formula (I), when heated with aqueous alkali, as the result of a double 1,4-cleavage, form diacetylene in accord with the scheme



$R^1 = R^2 = CH_3$; R (see Table)

To verify this postulation we synthesized a number of diquaternary ammonium salts having the general formulas (I) and (II). Salts (I) were obtained both by the reaction of 1,4-di-(dimethylamino)-2-chloro-2-butene with alkyl halides and by the reaction of 1,4-dibromo-2-chloro-2-butene with the corresponding dimethylalkylamines. Salts (II) were obtained by the reaction of alkyl bromides with 1,4-bis-(dimethylamino)-2-butyne.

A study of the alkaline cleavage of the obtained salts revealed that it actually leads to the formation of diacetylene and the tertiary amine. The cleavage was run with 10-40% aqueous sodium hydroxide solutions with heating on the water bath. The experiments, run in a nitrogen atmosphere, revealed that the formation of diacetylene proceeds even at room temperature (formation of copper acetylide).

The yields of the tertiary amines were close to quantitative, while those of the diacetylene were equal to 45-60%. In the cleavage of both salts (I) and (II), together with diacetylene, a black mass is formed (of

TABLE

Expt. Nos.	Quaternary salts of general formula (I) and (II) with R	Yield of salt (in %)	Melting point	Sample wt. (g) for halide ion determination	AgBr (in g)	Br (in %) found	Br (in %) calcd.	Products of cleavage with aqueous alkali	Yield of cleavage products (%) diacetylene	Yield of cleavage products (%) amine
1	CH_3 (I)	92	218-219 (decompn)	0.0966	0.0952	41.94	43.62	Diacetylene and $(CH_3)_3N$	53	86
2	CH_3 (II)	89	235 (decompn.)	0.0930	0.1022	46.78	48.4		54	88
3	C_2H_5 (I)	92	213-215 (decompn)	0.0808	0.0775	40.81	40.5	Diacetylene and $(CH_3)_2NC_2H_5$	47	79
4	C_2H_5 (II)	97	210 (decompn.)	0.0820	0.0851	44.15	44.6		61	88
5	n-C_3H_7 (I)	90	108-109	0.0968	0.0888	38.9	37.8	Diacetylene and $(CH_3)_2NC_3H_7$	49.7	82.6
6	n-C_3H_7 (II)	82	109 (decompn.)	0.0936	0.0965	40.73	41.16		45	89.8
7	n-C_4H_9 (II)	82	89	0.0936	0.0844	38.36	38.6	Diacetylene and $(CH_3)_2NC_4H_9$	52	93
8	iso-C_5H_{11} (I)	95	—	0.0978	0.0784	34.1	33.4	Diacetylene and $(CH_3)_2NC_5H_{11}$	61.6	84.5

similar composition in both cases), which we have failed as yet to study closer. The diacetylene was identified by the preparation of the crystalline hexabromo-3-butene, while the tertiary amines were identified by the melting points of their picrates. The results are given in the Table. We believe that this reaction can be used as a laboratory method for the preparation of diacetylene.

EXPERIMENTAL

1. 1,4-Bis-(dimethylamino)-2-butyne was obtained in accord with [5] with slight modifications, as, for example: replacement of the ethyl alcohol by methyl, a shorter heating time (3 hours instead of 20), and extraction of the reaction product by steam-distillation, — which lead to a higher yield (87% instead of 68%).

2. The 2-chloro-2-butene- and 2-butyne-1,4-di-(trialkylammonium bromides) were obtained by the reaction of an alkyl bromide with 1,4-dimethylamino-2-chloro-2-butene and 1,4-dimethylamino-2-butyne, respectively. The reaction with the methyl bromide was run in ether medium and with cooling; in the other cases the reaction was run in the absence of a solvent — by mixing stoichiometric amounts of the diamine and alkyl bromide. Heating on the water bath was required to complete the reaction in the case of the propyl and butyl bromides. The reaction mixture crystallized completely. The obtained salts were recrystallized from alcohol (see Table).

3. Alkaline cleavage of 2-butyne- and 2-chloro-2-butene-1,4-(trialkylammonium bromides). To a solution of 0.6 mole of sodium hydroxide in 20 ml of water was added a solution of 0.075 mole of the diquaternary ammonium salt in 30 ml of water. The mixture was heated on the water bath. A wash-bottle, containing standard acid solution, was inserted between the first receiver, cooled with water, and the second, kept at -25 to -30°. The amount of amine in the condensate and that present in the acid absorber was determined by titration. The weight of the diacetylene was determined by the weight of the condensate in the second receiver. This condensate gives a dark-red precipitate with Ilosvay solution, and with bromine water it gives a crystalline bromide with m.p. 181°, which corresponds to 1,1,2,3,4,4-hexabromo-3-butene [6]. The obtained data are given in the Table.

4. Preparation of diacetylene. To a mixture of 46 g (0.4 mole) of dimethylisoamylamine and 36 ml of water was added 49.5 g (0.2 mole) of 1,4-dibromo-2-chloro-2-butene. To the obtained water solution of the diquaternary ammonium salt was added a solution of 48 g of sodium hydroxide in 44 ml of water. The mixture was heated on the water bath. In the receiver, cooled to -30°, 5.9 g (59%) of diacetylene was collected. Steam-distillation of the reaction mixture gave 36 g (79%) of dimethyl-

isoamylamine, b.p. 107-109° at 680 mm, m.p. of the picrate 131.5° [7]. The obtained diacetylene was bubbled through 50% aqueous potassium hydroxide solution, containing acetone. A crystalline product with m.p. 131° was formed, which corresponds to 2,7-dimethyl-3,5-octadiyn-2,7-diol [8].

SUMMARY

It was shown that 2-butyne-1,4-di-(trialkylammonium bromides) when heated with aqueous sodium hydroxide solution suffer cleavage with the formation of the tertiary amine and diacetylene. Under similar conditions the 2-chloro-2-butene-1,4-di-(trialkylammonium bromides) suffer both dehydrochlorination and cleavage, as a result of which the tertiary amines and diacetylene are obtained. The obtained diquaternary salts are new. A laboratory method for the preparation of diacetylene is proposed.

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* Original Russian pagination. See C. B. Translation.

STUDY OF THE ABSORPTION SPECTRA OF THE 2,4-DINITROPHENYLHYDRAZONES OF CARBONYL COMPOUNDS

I. N. Nazarov, L. A. Kazitsyna and I. I. Zaretskaya

In view of their ease of purification, stability and high absorption coefficient ($\log \epsilon$ 4-4.5 instead of $\log \epsilon$ 1.5-2.0 for ketones), the absorption spectra of the 2,4-dinitrophenylhydrazones are very frequently used for the identification of carbonyl compounds. In accord with the literature data [1-6], the spectra of the 2,4-dinitrophenylhydrazones show characteristic absorption bands of high intensity, depending on the structure of the starting carbonyl compounds, but this dependence is expressed to a weaker degree than for the carbonyl compounds themselves. Thus, for example, if the absorption bands in the spectra of conjugated dienones and enones differ by 40 mμ, then the absorption bands of their 2,4-dinitrophenylhydrazones differ by only 12-14 mμ.

Absorption spectra are usually measured in solutions, and the solvents exert a variable influence on the spectrum of the dissolved substance. In all of the studies described up to now on the absorption spectra of 2,4-dinitrophenylhydrazones either ethyl alcohol or chloroform has been used as the solvent, preferably the latter, in view of its more universal character. In this connection it was experimentally established that the bathochromic shift in 2,4-dinitrophenylhydrazones is equal to 10-20 mμ for a conjugated ethylene bond and 5-10 mμ for an alkyl substitutent. The influence of the solvent is expressed in a shift of the absorption maximum, the magnitude of which varies from 1 to 10 mμ in which connection the absorption intensity changes slightly [1]. It is known that of all of the solvents used in absorption spectroscopy the most inert, and practically without influence on the spectrum of the dissolved substance, are the saturated hydrocarbons. However, in veiw of the poor solubility of the 2,4-dinitrophenylhydrazones in them, the hydrocarbon solvents have not been used up to now for this purpose. As our study revealed, due to the high absorption intensity shown by 2,4-dinitrophenylhydrazones, for taking their spectra it is quite sufficient to use a molar concentration of the order of 10^{-4}, and most dinitrophenylhydrazones show such a solubility in saturated hydrocarbons. As a result, the saturated hydrocarbons prove to be not only fully suitable, but also the most convenient solvents for studying the absorption spectra of the 2,4-dinitrophenylhydrazones of carbonyl compounds.

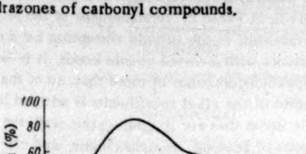

Fig. 1. Absorption spectrum of 2,4-dinitrophenylhydrazine in alcohol.

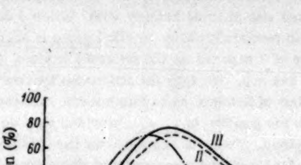

Fig. 2. Absorption spectrum of the 2,4-dinitrophenylhydrazone of mesityl oxide in isooctane (I), in alcohol (II), and in chloroform (III).

We took the absorption spectra of the 2,4-dinitrophenylhydrazones of more than 100 carbonyl compounds, of variable structure and of variable unsaturation, in isooctane solution. The obtained results permitted us to derive the dependence of the absorption spectra of 2,4-dinitrophenylhydrazones on the conjugated unsaturation and variable degree of alkyl substitution shown by carbonyl compounds.

In the 300-460 mμ region the spectrum of 2,4-dinitrophenylhydrazine itself in chloroform and alcohol solutions has one absorption band with $\lambda_{max.}$ 348 mμ (see Fig. 1). In the 300-460 mμ region the spectra of the 2,4-dinitrophenylhydrazones of carbonyl compounds in isooctane solution contain two absorption bands—one in the 410 mμ region, and the other, more intense, in the 330-380 mμ region. The absorption spectra of the 2,4-dinitrophenylhydrazones in chloroform and alcohol, similar to the spectrum of 2,4-dinitrophenylhydrazine itself in these solvents, have one absorption band, probably for the reason that under the influence of solvents the two bands merge. The absorption spectra for the 2,4-dinitrophenylhydrazone of mesityl oxide in isooctane, methyl alcohol and chloroform are shown in Fig. 2.

The position of the less intense absorption band of the 2,4-dinitrophenylhydrazones in isooctane solution does not depend on the structure of the original carbonyl compounds. The position of the second, more intense, absorption band of the 2,4-dinitrophenylhydrazones of saturated carbonyl compounds is determined by the presence of an alkyl substituent on the carbonyl carbon, while in the case of unsaturated conjugated carbonyl compounds the position of the intense absorption band of the 2,4-dinitrophenylhydrazones is determined by the conjugated unsaturation of the original carbonyl compound and the presence of an alkyl substituent in the α-position to the carbonyl, and then in succession in the β-position along the vinylog chain.

We arranged all of the experimental material obtained in our study of the absorption spectra of 2,4-dinitrophenylhydrazones by the degree of alkyl substitution of the original carbonyl compound, and in the tables we give the $\lambda_{max.}$ and $\epsilon_{max.}$ of the intense absorption band, the position of which depends on the structure of the original carbonyl compound (Tables 1-4).

In Table 1 we give the $\lambda_{max.}$ and $\epsilon_{max.}$ of the intense absorption band for the 2,4-dinitrophenylhydrazones of aldehydes. For the 2,4-dinitrophenylhydrazone of formaldehyde $\lambda_{max.}$ is found at 330 mμ and replacement of one of the hydrogens by an alkyl radical causes a shift of 7 mμ in the absorption band. The character of the alkyl substituents is without influence on the position of $\lambda_{max.}$, provided they do not contain double bonds in conjugation with the carbonyl, and for acetaldehyde, butyraldehyde, hexahydrobenzaldehyde and Δ^3-tetrahydrobenzaldehyde the $\lambda_{max.}$ of the intense absorption band is equal to 337 mμ (Table 1, Compound 2-5). The introduction of a double bond in conjugation with the aldehyde group causes a shift of 17 mμ toward the visible region in the position of the absorption maximum, and for acrolein $\lambda_{max.}$ = 347 mμ (Table 1, Compound 6). The introduction of an alkyl substituent in the methylene group gives a further shift of the absorption band toward the visible region by 7 mμ and for crotonaldehyde $\lambda_{max.}$ = 354 mμ while for Δ^1-tetrahydrobenzaldehyde $\lambda_{max.}$ = 359 mμ (Table 1, Compounds 7 and 8). Further introduction of substituents into acrolein (either alkyl radicals or substituents, containing conjugated double bonds) causes the appearance in the absorption spectrum of a weakly expressed vibrational structure (the corresponding wavelengths are given in Table 1).

The measurement results for the absorption spectra of the 2,4-dinitrophenylhydrazones of some saturated ketones, and also of some ketones with isolated double bonds, are given in Table 2. Replacement of the second hydrogen in formaldehyde by an alkyl group is accompanied by a further shift of the intense absorption band on an average of 7 mμ and for the saturated ketones, and also for the ketones with isolated double bonds, it is found at around 344 mμ. We took the absorption spectra of the 2,4-dinitrophenylhydrazones of more than 30 of the indicated class of ketones, and again became convinced that the character of the alkyl substituents is without influence on the position of $\lambda_{max.}$, provided they do not contain double bonds that are in conjugation with the carbonyl group. Thus, for example, for the 2,4-dinitrophenylhydrazones of acetone, cyclohexanone, and cis- and trans-decalones the wavelength of the absorption maximum is found at around 344-345 mμ.* This value is also retained for those unsaturated ketones in which the double bond is not found in conjugation with the carbonyl group (Table 2, Compounds 21-28,30), and is only slightly lower for the tetrahydrofuran derivatives (341 mμ). Only for the 2,4-dinitrophenylhydrazones of such compounds as acetoacetic ester and diacetyl is $\lambda_{max.}$ = 336 mμ.

The same as in the case of the aldehydes, the introduction of a double bond in conjugation with the ketone group causes the intense absorption band to shift toward the red region by an average of 17 mμ, and for the 2,4-dinitrophenylhydrazone of methyl isopropenyl ketone $\lambda_{max.}$ = 353 mμ (Table 3, Compound 1). In a similar manner, β-alkyl substitution in α,β-unsaturated ketones causes the intense absorption band to shift by an average

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*For all of the cis-trans-isomers of the carbonyl compounds investigated by us we failed to observe any changes in the absorption spectra of the 2,4-dinitrophenylhydrazones.

TABLE 1

Absorption Spectra of the 2,4-Dinitrophenylhydrazones of Aldehydes (in Isooctane Solution

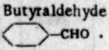
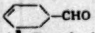
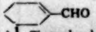
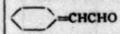
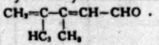
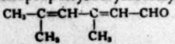
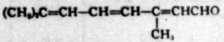
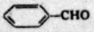
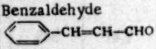
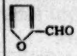
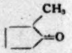
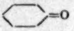
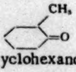
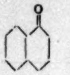
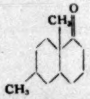
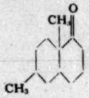
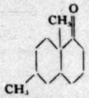
Expt. Nos.	Structural formula and name of aldehyde	2,4-Dinitrophenylhydrazones			
		melting point	molar con. in soln. (x10^4)	λ_{max} (in mμ)	ϵ_{max}
1	HCHO Formaldehyde	167°	—	330	—
2	CH_3CHO Acetaldehyde	162—163	—	336	—
3	$CH_3CH_2CH_2CHO$ Butyraldehyde	123	1.90	337	21000
4	 Hexahydrobenzaldehyde	172	3.51	338	—
5	 Δ^3-Tetrahydrobenzaldehyde	176—177	3.28	337	19000
6	$CH_2{=}CHCHO$ Acrolein	162	1.87	347	19000
7	$CH_3CH{=}CH{-}CHO$ Crotonaldehyde	189	1.17	354	22000
8	 Δ^1-Tetrahydrobenzaldehyde	219	1.33	359	21000
9	$(CH_3)_2C{=}CHCHO$ Dimethylacrylaldehyde	179	—	350 366 320	—
10	$CH_3(C_2H_5)C{=}CHCHO$ Methylethylacrylaldehyde	169	—	352 365 380	—
11	 Cyclohexylideneacetaldehyde	194—195	—	354 365	—
12	 $CH_2{=}\underset{HC_3}{\underset{\mid}{C}}{-}\underset{CH_3}{\underset{\mid}{C}}{=}CH{-}CHO$ Methylisopropenylacrylaldehyde	160	—	358 372 388	—
13	 $CH_3{-}\underset{CH_3}{\underset{\mid}{C}}{=}CH{-}\underset{CH_3}{\underset{\mid}{C}}{=}CH{-}CHO$ 2,4-Dimethyl-2,4-hexadienal	140—141	—	362 370 387	—
14	$CH_3CH{=}CH{-}CH{=}CH{-}CH{=}CHCHO$ Octatrienal	189 (with decomp.)	—	372 390 406	—
15	 $(CH_3)_2C{=}CH{-}CH{=}CH{-}\underset{CH_3}{\underset{\mid}{C}}{=}CHCHO$ Dehydrocitral	211—212	—	381 397 420	—
16	 Benzaldehyde	234—235	—	362	—
17	 Cinnamaldehyde	250	—	372	—
18	 2-Furaldehyde	223	—	366	—

TABLE 2

Absorption Spectra of the 2,4-Dinitrophenylhydrazones of Saturated Ketones (in Isooctane Solution) *

Expt. Nos.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones			
		melting point	molar con. in soln. (x10^4)	λ_{max} (in mμ)	ϵ_{max}
1	CH_3COCH_3 Acetone	125°	3.36	344	17000
2	$CH_3COC_2H_5$ Methyl ethyl ketone	115	3.07	344	16000
3	$C_2H_5COC_2H_5$ Diethyl ketone	154	1.26	344	16000
4	$(CH_3)_2CHCOCH(CH_3)_2$ Diisopropyl ketone	91—92	1.18	345	17000
5	$CH_3CO(CH_2)_5CH_3$ Methyl n-hexyl ketone	58	1.29	345	17000
6	 1-Methyl-2-cyclopentanone	159—160	1.39	344	16000
7	 Cyclohexanone	163	2.44	345	18000
8	 1-Methyl-2-cyclohexanone	142	2.4	345	19000
9	 Cis-decalone	225	1.03	345	19000
10	 6 (β), 9-Dimethyl-1-decalone (cis)	181—182	1.48	346	18500
11	 6 (α),9-Dimethyl-1-decalone (cis)	152—153.5	1.7	346	18000
12	 6,9-Dimethyl-1-decalone (trans)	212—213	1.41	345	20000

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* The spectrum of the 2,4-dinitrophenylhydrazone of 2-methyl-2-hepten-6-one (No. 22) was taken in heptane solution.

TABLE 2 (continued)

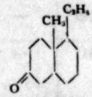
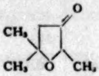
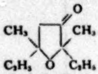
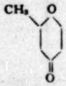
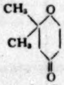
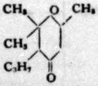
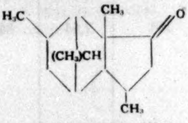
Expt. Nos.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones			
		melting point	molar con. in soln. (x10^4)	λ max (in mμ)	ε max
13	 Trans-9-methyl-1-ethyl-6-keto-decahydronaphthalene	156—157°	—	347	—
14	$CH_3COCH_2CH_2OCH_3$ β-Methoxyethyl methyl ketone	112—113	0.793	344	17000
15	 2,5,5-Trimethyltetrahydro-3-furanone	100—101	2.18	341	19000
16	 2,5-Dimethyl-2,5-diethyltetrahydro-3-furanone	131—132	1.13	341	18000
17	 2-Methyltetrahydro-4-pyrone	151—152	1.70	344	18000
18	 2,2-Dimethyltetrahydro-4-pyrone	143—146	2.97	344	22000
19	 2,2,6-Trimethyl-3-isopropyltetrahydro-4-pyrone	85—86	1.05	344	18000
20		184	5.23	345	19000
21	$C_2H_5COCH_2CH{=}CH_2$ Ethyl allyl ketone	118—119	2.05	344	19500
22	$(CH_3)_2C{=}CH{-}CH_2CH_2COCH_3$ 2-Methyl-2-hepten-6-one	88	1.89 (in heptane)	345	17500

TABLE 2 (Continued)

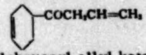
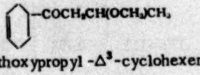
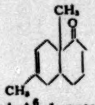
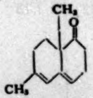
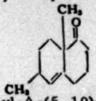
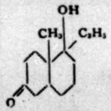
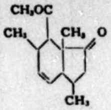
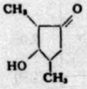
Expt. No.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones melting point	molar con. in soln. $(x10^{4})$	λ_{max} (in mμ)	ϵ_{max}
23	$(CH_3)_2C(OCOCH_3)COCH_2CH{=}CH_2$	121—122°	—	345	—
24	 Δ^3-Cyclohexenyl allyl ketone	83—84	—	346	18000
25	 β-Methoxypropyl-Δ^3-cyclohexenyl ketone	73—75	—	346	—
26	 6,9-Dimethyl-Δ^6-1-octalone (cis)	181—182	0.973	346	15000
27	 6,9-Dimethyl-6-keto-Δ-(4, 10;5, 6)-hexahydronaphthalene	138	1.19	346	17000
28	 6,9-Dimethyl-Δ-(5, 10)-1-octalone	200	1.44	346	18000
29	 Trans-9-methyl-1-ethyl-1-hydroxy-6-ketodecahydronaphthalene	205—206	—	346	—
30		164	2.54	345	17000
31	 1,3-Dimethyl-2-cyclopentanol-5-one	103—105	—	341	—

TABLE 2 (continued)

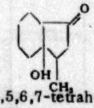
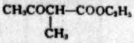
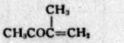
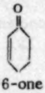
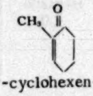
Expt. No.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones			
		melting point	molar con. in soln. ($\times 10^4$)	λ_{max} (in mμ)	ϵ_{max}
32	 1-Methyl-4,5,6,7-tetrahydroindan-8-ol-3-one	168—169°	0.86	341	18000
33	$CH_3COCH_2COOC_2H_5$ Acetoacetic ester	89—90	—	337	—
34	 $CH_3COCH(CH_3)-COOC_2H_5$ Methylacetoacetic ester	148—150	—	337	—
35	$CH_3COCOCH_3$ Diacetyl	169—170	—	336	—

TABLE 3

Absorption Spectra of the 2,4-Dinitrophenylhydrazones of α,β-Unsaturated Ketones (in Isooctane Solution)*

Expt. No.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones			
		melting point	molar con. in soln. ($\times 10^4$)	λ_{max} (in mμ)	ϵ_{max}
1	 $CH_3COC(CH_3)=CH_2$ Methyl isopropenyl ketone	191—192°	2.04	353	18000
2	$CH_3CH_2COCH=CH-CH_3$ Ethyl propenyl ketone	141—142	1.2	363	20000
3	$(CH_3)_2C=CHCOCH_3$ Mesityl oxide	199—200	1.11	364	18000
4	 Δ^1-Cyclohexen-6-one	165	1.92	362	25000
5	 1-Methyl-Δ^1-cyclohexen-6-one	206	2.14	362	22000

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*The spectrum of the 2,4-dinitrophenylhydrazone of propenyl Δ^3-cyclohexenyl ketone (No. 7) was taken in heptane solution.

TABLE 3 (continued)

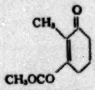
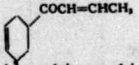
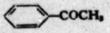
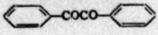
Expt. No.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones melting point	molar con. in soln. (x10^4)	λmax (in mμ)	ϵ max
6	 Methyldihydroresorcinol enolacetate	202—203°	—	362	—
7	 Propenyl Δ^3-cyclohexenyl ketone	125—126	0.828	362	19000
8	 Acetophenone	249	—	362	—
9	$CH_3C_6H_4COCH_3$ Methyl tolyl acetophenone	252—253	—	363	—
10	 Benzil	186—187	—	364	—

TABLE 4

Absorption Spectra of the 2,4-Dinitrophenylhydrazones of α,β-Diunsaturated Ketones

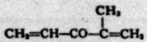
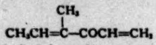
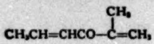
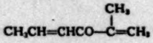
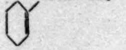
Expt. No.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones melting point	Solvent and molar con. in soln. (x 10^4)	λmax (in mμ)	ϵ max
1	 $CH_2=CH-CO-\overset{CH_3}{\overset{\vert}{C}}=CH_2$ Vinyl isopropenyl ketone	134—135°	Heptane 2.14	357	21000
2	 $CH_3CH=\overset{CH_3}{\overset{\vert}{C}}-COCH=CH_2$ 3-Methyl-2,5-hexadien-4-one	168	Heptane 1.92	362	21000
3	 $CH_3CH=CHCO-\overset{CH_3}{\overset{\vert}{C}}=CH_2$ Propenyl isopropenyl ketone (trans)	157	Isooctane 1.29	361	21000
4	 $CH_3CH=CHCO-\overset{CH_3}{\overset{\vert}{C}}=CH_2$ Propenyl isopropenyl ketone (cis)	125	Isooctane 1.27	362	21000
5	 Vinyl Δ^1-cyclohexenyl ketone	209	Heptane 1.0	362	18000

TABLE 4 (continued)

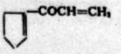
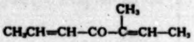
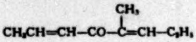
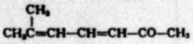
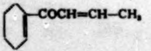
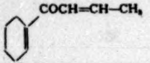
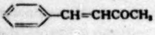
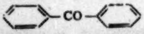
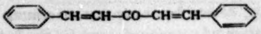
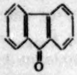
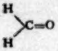
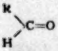
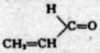
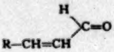
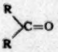
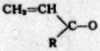
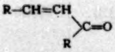
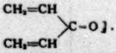
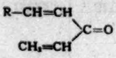
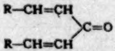
Expt. Nos.	Structural formula and name of ketone	2,4-Dinitrophenylhydrazones			
		melting point	Solvent and molar con. ($\times 10^4$)	λ_{max} (in mμ)	ϵ_{max}
6	 Vinyl Δ^1-cyclopentenyl ketone	205—206°	Isooctane	363	—
7	$CH_3CH{=}CH{-}CO{-}C(CH_3){=}CH{-}CH_3$ 3-Methyl-2,5-heptadien-4-one	158—159	Isooctane 1.22	371	22000
8	$CH_3CH{=}CH{-}CO{-}C(CH_3){=}CH{-}C_2H_5$ 4-Methyl-3,6-octadien-5-one	157—158	Isooctane	372	—
9	$CH_3C(CH_3){=}CH{-}CH{=}CH{-}CO{-}CH_3$ 2-Methyl-2,4-heptadien-6-one	209—210	Isooctane	372	—
10	 Propenyl Δ^1-cyclohexenyl ketone (trans)	168—169	Heptane 0.835	370	21000
11	 Propenyl Δ^1-cyclohexenyl ketone (cis)	189—190	Heptane 0.803	370	20000
12	 Benzalacetone	192	Isooctane	370	—
13	 Benzophenone	238—239	Isooctane	368	—
14	 Dibenzalacetone	180—181	Isooctane	387	—
15	 Fluorenone	294—295	Isooctane	378	—

TABLE 5

Absorption Spectra of the 2,4-Dinitrophenylhydrazones of Carbonyl Compounds as a Function of Alkyl Group Substitution and Conjugated Unsaturation

Carbonyl compound	Found λ_{max} (in mμ)	Shift (in mμ) with respect to formaldehyde	Calculated $\lambda_{max.}$ (in mμ)
	330	0	—
	337	7	337
	347	17	347
	354—357	24—27	354
	345	15	344
	352	22	354
	362—363	32—33	361
	357	27	356
	361—362	31—32	363
	370—371	40—41	370

of 7 mμ, and for ethyl propenyl ketone, mesityl oxide, Δ^1-cyclohexenone, 1-methyl-Δ^1-cyclohexenone and propenyl Δ^3-cyclohexenyl ketone $\lambda_{max.}$ = 362-364 mμ (Table 3, Compounds 2-7). The introduction of a second double bond, found in conjugation with the carbonyl group, causes the absorption maximum to shift on an average of 9 mμ (when compared with the corresponding unsaturated compound), and for the 2,4-dinitrophenylhydrazone of vinyl isopropenyl ketone $\lambda_{max.}$ = 357 mμ (Table 4, Compound 1). For the conjugated dienones, having one β-alkyl substituent, $\lambda_{max.}$ = 361-364 mμ (Table 4, Compounds 3-6), and in the case of the conjugated dienones with two and more β-alkyl substituents (in both vinyl groups) $\lambda_{max.}$ = 370-372 mμ (Table 4, Compounds 7-11). It should be mentioned that a shift of the absorption maximum by 7 mμ occurs only in the introduction of the first alkyl substituent in the β-position of α,β-unsaturated ketones, and that the introduction of a second alkyl substituenton the same carbon atom (the same as in the case of α-substitution) is already without influence on the position of the absorption maximum (see Compounds 2-7 in Table 3 and Compounds 2-11 in Table 4).

The relative shift of the intense absorption band of the 2,4-dinitrophenylhydrazones of aldehydes and ketones as a function of conjugated unsaturation and alkyl substitution is shown in Figs. 3,4 and 5.

We summarized the experimental material obtained by us in a general table, dividing all of the studied carbonyl compounds into groups by the degree of alkyl substitution and the character of the conjugated unsaturation (Table 5). For all of the studied groups of carbonyl compounds the shift in the absorption maxima of the

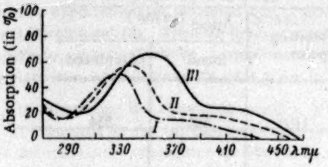


Fig. 3. Absorption spectra of the 2,4-dinitrophenylhydrazones of formaldehyde (I), butyraldehyde (II) and crotonaldehyde (III).

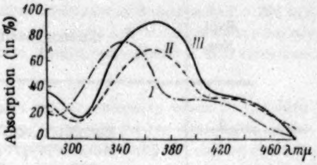


Fig. 4. Absorption spectra of the 2,4-dinitrophenylhydrazones of acetone (I), mesityl oxide (II) and propenyl isobutenyl ketone (Table 4, Compound 7) (III).

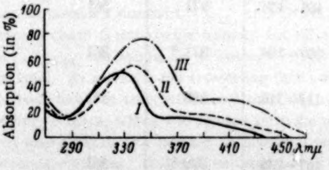


Fig. 5. Absorption spectra of the 2,4-dinitrophenylhydrazones of formaldehyde (I), butyraldehyde (II) and acetone (III).

2,4-dinitrophenylhydrazones was calculated relative to $\lambda_{\text{max.}}$ of the 2,4-dinitrophenylhydrazone of formaldehyde. The differences that we obtained here are given in Column 3 of Table 5. Analysis of these data revealed that the introduction of an alkyl group on the carbonyl, and also in the β-position of the conjugated or vinolog chain causes a shift of 7 mμ in $\lambda_{\text{max.}}$; the introduction of the first conjugated double bond causes $\lambda_{\text{max.}}$ to shift by 17 mμ, and subsequent conjugated double bonds causes it to shift by 9 mμ. Consequently, taking the wavelength of the absorption maximum of the formaldehyde 2,4-dinitrophenylhydrazone (330 mμ) as a base, it becomes possible to calculate the wavelengths of the absorption maxima of the 2,4-dinitrophenylhydrazones of aldehydes and ketones of variable structure. The $\lambda_{\text{max.}}$ of the 2,4-dinitrophenylhydrazones of carbonyl compounds, calculated in this manner, are given in Column 4 of Table 5. A comparison of the calculated and experimentally found values of $\lambda_{\text{max.}}$ reveals that they lie within the limits of experimental error. To verify the derived dependence of $\lambda_{\text{max.}}$ of the 2,4-dinitrophenylhydrazones of carbonyl compounds on alkyl substitution and conjugated unsaturation we took the absorption spectra of the 2,4-dinitrophenylhydrazones of a number of carbonyl compounds.

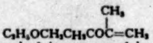
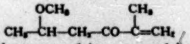
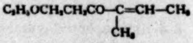
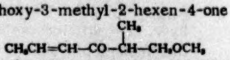
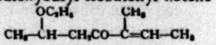
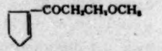
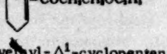
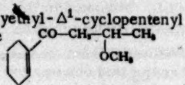
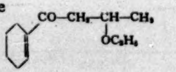
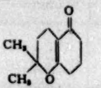
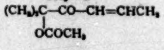
TABLE 6

Carbonyl compound	λ_{max} of the 2,4-dinitrophenylhydrazones (in mμ)	
	measured	calculated
Benzaldehyde	362	354
Cinnamaldehyde	372	361
Acetophenone	362	361
Methyl tolyl ketone	363	361
Benzil	364	361
Benzophenone	368	370
Benzalacetone	370	370
Dibenzalacetone	387	388

From the literature it is known that the benzene ring exerts the same influence as one conjugated bond [7] on the absorption spectrum, and the furan ring the same influence as two conjugated double bonds. For the 2,4-dinitrophenylhydrazone of 2-furaldehyde we calculated $\lambda_{\text{max.}} = 330 + 17 + 9 + 7 = 363$ mμ, where 17 is

TABLE 7

Absorption Spectra of the 2,4-Dinitrophenylhydrazones of β-Alkoxy Ketones (in Isooctane Solution) *

Expt. Nos.	Carbonyl compound	2,4-Dinitrophenylhydrazones		
		melting point	λ_{max} (in mμ) found	λ_{max} (in mμ) calculated
1	 $C_2H_5OCH_2CH_2CO\overset{CH_3}{C}=CH_2$ β-Ethoxyethyl isopropenyl ketone	115°	360	354
2	 $CH_3-\overset{OCH_3}{CH}-CH_2-CO-\overset{CH_3}{C}=CH_2$ β-Methoxypropyl isopropenyl ketone	107—108	372	354
3	$C_2H_5OCH_2CH_2COCH=CHCH_3$ β-Ethoxyethyl propenyl ketone	125	365	361
4	 $C_2H_5OCH_2CH_2CO-\underset{CH_3}{C}=CH-CH_3$ 6-Ethoxy-3-methyl-2-hexen-4-one	125	367	361
5	 $CH_3CH=CH-CO-\overset{CH_3}{CH}-CH_2OCH_3$ β-Methoxyisopropyl propenyl ketone	105—106	371	361
6	$CH_3OCH_2CH_2COCH=C(CH_3)_2$ β-Methoxyethyl isobutenyl ketone	107—108	371 *	361
7	 $CH_3-\overset{OC_2H_5}{CH}-CH_2CO-\overset{CH_3}{C}=CH-CH_3$ 6-Ethoxy-3-methyl-2-hepten-4-one	117—118	370	361
8	 β-Methoxyethyl-Δ^1-cyclopentenyl ketone	127—128	370 *	361
9	 β-Ethoxyethyl-Δ^1-cyclopentenyl ketone	128	368	361
10	 β-Methoxypropyl-Δ^1-cyclohexenyl ketone	118—119	370	361
11	 β-Ethoxypropyl-Δ^1-cyclohexenyl ketone	125—126	371	361
12		240—241	373	361
13	 $(CH_3)_2\underset{OCOCH_3}{C}-CO-CH=CHCH_3$	131—132	350	361

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* The spectra of the 2,4-dinitrophenylhydrazones of β-methoxyethyl isobutenyl ketone (No. 6) and β-methoxyethyl Δ^1-cyclopentenyl ketone (No. 8) were taken in heptane solution.

the shift in mμ when the first conjugated double bond is introduced, 9 is the shift in mμ when the second conjugated double bond is introduced, and 7 is the shift in mμ as the result of substitution along the vinylog chain (in the case of 2-furaldehyde—the structure of the ring).

The experimentally measured $\lambda_{max.}$ of the 2,4-dinitrophenylhydrazone of 2-furaldehyde = 366 mμ (Table 1, Compound 18). Then we measured and calculated the $\lambda_{max.}$ of the 2,4-dinitrophenylhydrazones of benzaldehyde, cinnamaldehyde, acetophenone, methyl tolyl ketone, benzil, benzophenone, benzalacetone and dibenzalacetone, and obtained the data given in Table 6.

In calculating the absorption maxima, given in Table 6, we used the following values for the shifts (in mμ): 17—the shift for the introduction of the first conjugated bond, 9—the shift for the introduction of the second and subsequent conjugated double bonds, and 7—the shift for substitution along the vinylog chain (a ring structure is equivalent to substitution by an alkyl).

As can be seen from the data in Table 6, the obtained relationship is also supported on the example of aromatic ketones. However, there are a number of carbonyl compounds that do not obey the derived relationship: these are, first, the unsaturated β-alkoxy ketones, showing conjugation of a double bond with the carbonyl group, second, derivatives of the Δ^1-cyclopentenones, and last, the aldehydes of more complex structure. The measured $\lambda_{max.}$ of the absorption spectra of the 2,4-dinitrophenylhydrazones of the unsaturated β-alkoxy ketones with conjugated double bonds are given in Table 7. From these data it can be concluded that nearly all of these hydrazones possess a constant $\lambda_{max.}$ at 370-373 mμ, and here the effect of substitution on the alkyl group along the vinylog chain is not always traced. For all of the unsaturated β-alkoxy ketones the experimentally found values of $\lambda_{max.}$ are raised by an average of 9 mμ, i.e., the β-alkoxy group in these compounds imitates a second double bond. As a result, the interesting fact was established that unsaturated β-alkoxy ketones with a conjugated double bond have an absorption maximum that is characteristic for the conjugated dienones (divinyl ketones) corresponding to them, which are formed from the unsaturated β-alkoxy ketones by the cleavage of alcohols. This analogy also extends to a number of chemical reactions, in particular, the reaction with ammonia, primary amines and secondary amines. It should be emphasized that the saturated β-alkoxy ketones show a normal absorption spectrum, obeying the above outlined rules. The acetoxy group in α,β-unsaturated acetoxy ketones produces the opposite effect, i.e., the $\lambda_{max.}$ in this case is considerably smaller than the calculated (Table 6, Compound 13).

The absorption spectra of the 2,4-dinitrophenylhydrazones of the cyclopentenones with a conjugated double bond have a different character when compared with the 2,4-dinitrophenylhydrazones of ordinary ketones: a weakly expressed vibrational structure is observed in them. We took the absorption spectra of the 2,4-dinitrophenylhydrazones of 9 cyclopentenones of variable structure and obtained similar spectra for all of the investigated compounds (Table 8). In the case of the Δ^1-cyclopentenones the deviation from standard behavior seems to us to be completely in order in view of the considerable strain shown by the cyclopentene ring. The absorption spectra of the 2,4-dinitrophenylhydrazones of the cyclopentanones already have the usual character. The appearance of a weakly expressed vibrational structure is also observed for the more complex unsaturated aldehydes (Table 1, Compounds 9-15), and to trace the derived relationship in this case does not seem possible. The values of $\lambda_{max.}$ also deviate from the calculated for benzaldehyde and cinnamaldehyde (Table 1, Compounds 16 and 17).

Our study shows that the absorption spectra of the 2,4-dinitrophenylhydrazones can be used to determine the structure of aldehydes and ketones, and in particular, to establish the position of the double bond in unsaturated ketones, which is frequently difficult to determine by chemical methods. For example, the oxidation of allyl-Δ^3-cyclohexenylcarbinol with chromic mixture at 5-10° in a solution of 2N sulfuric acid and dioxane gave two isomeric dienones, which could be identified through their 2,4-dinitrophenylhydrazones. Here it was found that the 2,4-dinitrophenylhydrazone with m.p. 83-84° has $\lambda_{max.}$ 346 mμ, ϵ = 18,000, which corresponds to the allyl Δ^3-cyclohexenyl ketone derivative (Table 2, Compound 24); the 2,4-dinitrophenylhydrazone with m.p. 125-126° has $\lambda_{max.}$ 362 mμ and ϵ = 18,000, characteristic for the dienone with one conjugated double bond, i.e., it is the hydrazone of propenyl Δ^3-cyclohexenyl ketone (Table 3, Compound 7). From the character of the absorption spectra of the 2,4-dinitrophenylhydrazones it follows that under the conditions used to oxidize the indicated carbinol there occurs under the influence of sulfuric acid a shift of the double bond in allyl Δ^3-cyclohexenyl ketone from the β,γ- to the α,β-position

TABLE 8

Absorption Spectra of the 2,4-Dinitrophenylhydrazones of Some Cyclopentenones (in Isooctane Solution)

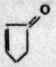
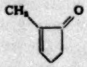
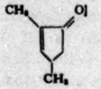
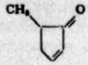
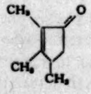
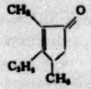
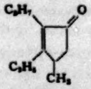
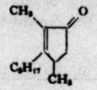
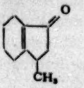
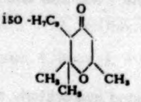
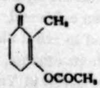
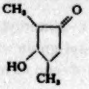
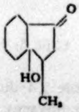
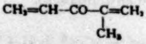
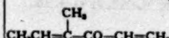
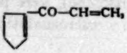
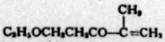
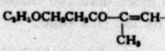
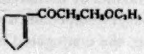
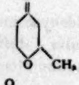
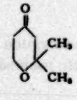
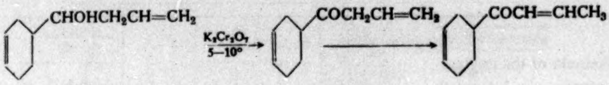
Expt. Nos.	Carbonyl compound	2,4-Dinitrophenylhydrazones melting point	λ max (in mμ)
1		167—168°	348 361 376
2		219—220	354 365 385
3		211	357 376 392
4		184—185	353 371 387
5	 CH₃ O CH₃ CH₃	173	357 376 392
6	 CH₃ O C₂H₅ CH₃	165	354 376 395
7	 C₃H₇ O C₂H₅ CH₃	127—128	354 376 395
8	 CH₃ O C₈H₁₇ CH₃	99—100	354 376 392
9		246—247	359 376 393

TABLE 9

Analyses of the New 2,4-Dinitrophenylhydrazones

Expt. Nos.	Formula of the original ketone	Melting point of the 2,4-dinitrophenylhydrazone	Found (in %)			Empirical formula	Calculated (in %)		
			C	H	N		C	H	N
1		85—86°	56.04	6.6	15.6	$C_{17}H_{24}O_5N_4$	56.04	6.6	15.4
2		202—203	—	—	16.4	$C_{15}H_{16}O_6N_4$	—	—	16.1
3		103—105	—	—	17.99. 18.27	$C_{13}H_{16}O_5N_4$	—	—	18.18
4		168—169	—	—	16.22. 15.88	$C_{16}H_{20}O_5N_4$	—	—	16.08
5	 $CH_2=CH-CO-\underset{CH_3}{C}=CH_2$	134—135	52.22. 52.0	4.51. 4.36	—	$C_{12}H_{12}O_4N_4$	52.11	4.37	—
6	 $CH_3CH=\overset{CH_3}{C}-CO-CH=CH_2$	168	53.36. 53.64	5.07. 4.89	—	$C_{13}H_{14}O_4N_4$	53.77	4.86	—
7		205—206	—	—	18.79. 18.87	$C_{14}H_{14}O_4N_4$	—	—	18.53
8	$C_2H_5OCH_2CH_2COCH=CH-CH_3$	125	52.26. 52.25	5.39. 5.49	—	$C_{14}H_{18}O_5N_4$	52.16	5.63	—
9	 $C_2H_5OCH_2CH_2CO-\overset{CH_3}{C}=CH_2$	115	52.26. 52.25	5.59. 5.59	—	$C_{14}H_{18}O_5N_4$	52.16	5.63	—
10	 $C_2H_5OCH_2CH_2CO-\underset{CH_3}{C}=CH-CH_3$	125	53.47. 53.25	6.05. 5.99	—	$C_{15}H_{20}O_5N_4$	53.4	6.27	—
11		128	54.97. 55.56	6.06. 5.79	—	$C_{16}H_{20}O_5N_4$	55.1	5.75	—
12		151—152	48.09. 48.26	4.78. 4.86	—	$C_{12}H_{14}O_5N_4$	48.9	4.78	—
13		143—146	50.67, 50.64	5.35. 5.31	—	$C_{13}H_{16}O_5N_4$	50.65	5.20	—



The presence of isolated double bonds in Compounds 21-23 of Table 2 was also established by this method.

EXPERIMENTAL

A mixture of 1 g of 2,4-dinitrophenylhydrazine, 1 ml of concentrated hydrochloric acid, 45 ml of ethyl alcohol and 5 ml of dioxane was boiled until complete solution had been achieved, and after cooling, the filtered solution was treated with a cold solution of the carbonyl compound in ethyl alcohol. The deposited 2,4-dinitrophenylhydrazones were recrystallized to constant melting point from ethanol, ethyl acetate, or a mixture of these solvents. The data on the new 2,4-dinitrophenylhydrazones are given in Table 9.

When we attempted to obtain the 2,4-dinitrophenylhydrazone of β,β-dimethyldivinyl ketone by the indicated method there occurred the simultaneous addition of water to the vinyl group with the formation of the isooctane-insoluble 2,4-dinitrophenylhydrazone of 2-methyl-2-hexen-6-ol-4-one as bright-orange crystals with m.p. 197-198° (from a mixture of ethanol, ethyl acetate and dioxane).

Found %: C 50.35, 49.65; H 5.06, 5.02. $C_{13}H_{16}O_5N_4$. Calculated %: C 50.6; H 5.2.

Methyl vinyl ketone under these conditions gave an isooctane-insoluble 2,4-dinitrophenylhydrazone as orange crystals with m.p. 217° (from a mixture of ethanol, ethyl acetate and dioxane).

Found %: C 45.70, 45.70; H 4.28, 4.32. $C_{10}H_{10}N_4O_4$. Calculated %: C 48.0; H 4.78.

The solvents, used in studying the absorption spectra (heptane, isooctane), were purified by a 2-fold passage through silica gel. The samples of the hydrazones were weighed on a microanalytical balance, and the samples of the solvents were weighed on an analytical balance.

A Dianov-Klokov Model FP-1 spectrophotometer was used to take the spectra.

SUMMARY

1. The absorption spectra of the 2,4-dinitrophenylhydrazones of more than 100 carbonyl compounds in in a solution of saturated hydrocarbons (isooctane, heptane) were taken for the first time.

2. Taking the absorption spectrum of the 2,4-dinitrophenylhydrazone of formaldehyde as a base, it was shown that the position of the intense absorption band of the other carbonyl compounds is determined by the degree of alkyl substitution of the hydrogen atoms at the carbonyl group, the conjugated unsaturation of the carbonyl compound and β-substitution along the vinylog chain.

The introduction of the first conjugated double bond in the formaldehyde molecule causes a shift of 17 mμ in λ_{max}, the introduction of subsequent conjugated double bonds causes a shift of 9 mμ, while the effect of substitution on the alkyl groups at the carbonyl carbon and of β-substitution along the vinylog chain is expressed by a shift of 7mμ in λ_{max}.

3. The found rules permit calculating with sufficient accuracy the absorption spectra of various carbonyl compounds, and consequently make more reliable the use of the spectroscopic method for characterizing the structure of aldehydes and ketones.

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THE STRUCTURE OF THE HYDRATION PRODUCTS OF DIVINYLACETYLENE HYDROCARBONS

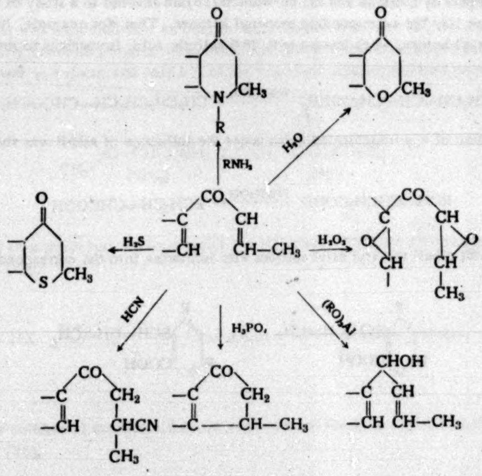
I. N. Nazarov and I. I. Zaretskaya

For a number of years a systematic study of the reaction for the hydration of divinylacetylene hydrocarbons (I) has been made in our laboratory. Studied at first on divinylacetylene itself and its simpler homologs [1], this reaction proved to be applicable to extremely different dienynes, containing aliphatic, alicyclic, aromatic, aralkyl and heterocyclic substituents [2]. Dienynes are hydrated in 80-90% methanol solution in the presence of mercury sulfate and sulfuric acid, and here the corresponding dienones are obtained in high yield. As a result, a simple and convenient method was found for the synthesis of various dienones, to which the structure of vinyl allyl ketones (II) was assigned, i.e., the normal products of the addition of water to a triple bond

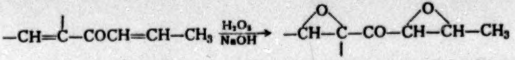
$$\underset{(I)}{\overset{|}{C}H{=}\overset{|}{C}{-}C{\equiv}C{-}CH{=}CH_2} \longrightarrow \underset{(II)}{\overset{|}{C}H{=}\overset{|}{C}{-}CO{-}CH_2{-}CH{=}CH_2} \longrightarrow \underset{(III)}{\overset{|}{C}H{=}\overset{|}{C}{-}CO{-}CH{=}CH{-}CH_3}$$

In the hydration of unsymmetrically substituted dienynes the water adds to the triple bond only in such a manner that the carbonyl group is formed in series with a substituted vinyl radical.

However, further studies in our laboratory revealed that the obtained dienones enter into various reactions only in the form of vinyl propenyl ketones (III). They readily add alcohols [3], amines [4], hydrogen sulfide [5], hydrogen cyanide [6], water [7] and hydrogen peroxide [8], and as a result can serve as the starting products for the synthesis of extremely different and difficultly available compounds. A very interesting characteristic of these dienones proved to be their exceptional ability to cyclize into substituted cyclopentenones under the influence of acids [9, 10].

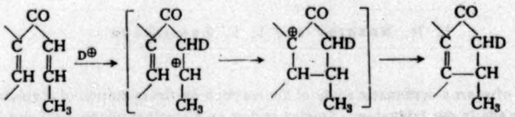


In studying the above mentioned reactions a number of facts were accumulated, placing in doubt the allyl structure of the dienones obtained in the hydration of compounds of the divinylacetylene series. Thus, the oxidation of the indicated dienones with alkaline hydrogen peroxide readily yields the corresponding keto diepoxides [8], and consequently, both of the double bonds in these dienones are conjugated with the keto group [11].

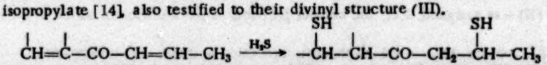


$$-CH=\overset{|}{C}-COCH=CH-CH_3 \xrightarrow[NaOH]{H_2O_2} -\overbrace{CH-\underset{|}{C}}^{O}-CO-\overbrace{CH-CH}^{O}-CH_3$$

In studying the reaction mechanism for the cyclization of these dienones by the method of labeled atoms it was also shown that it is not the vinyl allyl ketones (II) that enter into the cyclization, but instead it is their isomeric vinyl propenyl ketones (III) [12, 13].



The behavior of the dienones in a number of other reactions, as: the formation of dimercaptans when reacted with hydrogen sulfide in alkaline medium [5] and the formation of propenylcarbinols when reduced with aluminum isopropylate [14], also testified to their divinyl structure (III).



$$\overset{|}{C}H=\overset{|}{C}-CO-CH=CH-CH_3 \xrightarrow{H_2S} -\overset{SH}{\overset{|}{C}H}-\overset{|}{C}H-CO-CH_2-\overset{SH}{\overset{|}{C}H}-CH_3$$

However, none of the above indicated reactions could appear as direct proof for the structure of the dienones obtained in the direct hydration of dienynes, since the conditions under which they were run (either a strongly acid or alkaline medium) could have caused isomerization of the formed vinyl allyl ketones (II) into vinyl propenyl ketones (III). A number of examples are described in the literature for this type of isomerization under the influence of acid, alkaline and other agents.

In 1905 Blaise was the first to establish that the alkyl allyl ketones, obtained by the reaction of allylzinc iodide with the nitriles of acids, easily isomerize into alkyl propenyl ketones [15].

$$RCOCH_2CH=CH_2 \rightarrow RCOCH=CHCH_3$$

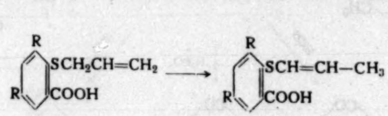
A number of papers by Linstead and his co-workers [16] are devoted to a study of the isomerization of ketones of the allyl type into the corresponding propenyl ketones. Thus, for example, it was shown by them that methyl β,γ-pentenyl ketone, when heated with 20% sulfuric acid, isomerizes to methyl α,β-pentenyl ketone in 75% yield.

$$CH_3CH_2CH=CH-CH_2COCH_3 \xrightarrow{20\%\,H_2SO_4} CH_3CH_2CH_2CH=CHCOCH_3$$

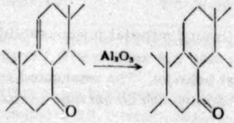
The isomerization of β,γ-unsaturated acids under the influence of alkali was studied in detail by Fittig [17].

$$RCH=CHCH_2COOH \xrightarrow{10\%\,NaOH} RCH_2CH=CHCOOH$$

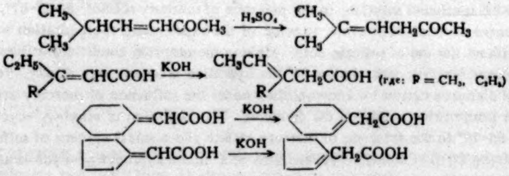
When heated with alkali the aryl allyl sulfides also isomerize into the corresponding aryl propenyl sulfides [18].



The ease with which the isolated β, γ-double bond is shifted into the conjugated α, β-position is illustrated by many other examples in the literature. It is known that the oxidation of β, γ-unsaturated steroid alcohols by the Oppenauer technique is accompanied by a simultaneous shift of the double bond into the conjugated position [19]. This type of isomerization was observed even in the oxidation of steroid alcohols with manganese dioxide in neutral solvents [20]. The interesting fact was recently described of a shift of the β, γ-double bond in steroid ketones into the α, β-position during chromatographing on aluminum oxide [21].



However, in not all of these cases is the α, β-form with a conjugated double bond the most stable form. In a number of his papers Linstead revealed that in ketones and acids with an isostructure the most stable is the β, γ-form with an isolated double bond [22].

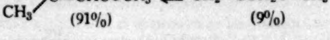


$$(CH_3)_2CHCH{=}CHCOCH_3 \xrightarrow{H_2SO_4} (CH_3)_2C{=}CHCH_2COCH_3$$

$$C_2H_5(R)C{=}CHCOOH \xrightarrow{KOH} CH_3CH{=}C(R)CH_2COOH \quad (R = CH_3,\ C_2H_5)$$

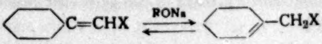
Many unsaturated ketones when treated with isomerizing agents give an equilibrium mixture of α, β- and β, γ-forms.

A long time ago it was indicated that an equilibrium mixture is present in mesityl oxide [23], however, only in 1947, using a highly efficient column, were Stross and Monger able to establish that this mixture contains 91% of the conjugated α, β-form and only 9% of the β, γ-form with an isolated double bond [24].



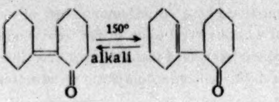
$$(CH_3)_2C{=}CHCOCH_3 \rightleftarrows CH_2{=}C(CH_3)CH_2COCH_3$$
$$(91\%) \qquad (9\%)$$

The formation of an equilibrium mixture under the influence of sodium alcoholates was also established in various cyclic systems [25].



where X = COCH₃, COOH, COOC₂H₅, C₆H₅, CN).

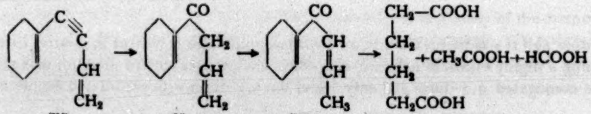
It was shown on a number of examples that the predominant formation of one or the other isomer depends on the isomerizing agent [26].



On the basis of a wealth of experimental material it was established that the ketones with an isolated β,γ-double bond are quite different from their α,β-isomers with a conjugated double bond as regards physical constants, absorption spectra and chemical behavior. The unsaturated ketones with isolated double bonds boil 8-10° lower, have a lower refraction and density, and do not show exaltation in calculating the molecular refraction.

The ultraviolet absorption spectra are an especially convenient method for establishing the position of a double bond in unsaturated ketones, the characteristic maxima of which permit clearly distinguishing between the isolated bonds and those found in conjugation with the carbonyl group.

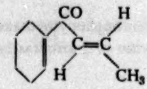
To answer the question of the position of the double bond in the hydrationproducts of the dienynes we again studied the hydration of vinyl-Δ^1-cyclohexenylacetylene (IV) [27], vinylisopropenylacetylene (XIX) [28] and 5-methyl-1,5-heptadien-3-yne (XXVI) [29]. The hydration of the dienynes was accomplished by the earlier developed method in 80% methanol solution, in the presence of mercury sulfate, at 65-67°. To avoid the isomerization of the dienones as much as possible, in some of the experiments the hydration was run in an extremely short period of time without the use of sulfuric acid. Making the reaction conditions milder by lowering the temperature did not appear feasible, since below 60° the hydration proceeds very slowly. For exactly the same reason the hydration of dienynes cannot be accomplished under the influence of mercury acetate, which could have exerted a smaller isomerizing action on the dienones. The hydration of vinyl-Δ^1-cyclohexenylacetylene (IV) for 30 minutes at 65-70° in the presence of mercury sulfate and a small amount of sulfuric acid (Expt. 1) gave a mixture, containing 80 % of dienone (VI) and 20% of β-methoxypropyl-Δ^1-cyclohexenyl ketone (VII). The ozonization of dienone (VI), distilled through a column, gave adipic acid and a mixture of formic and acetic acids, shown to contain 55 % of the first and 45% of the second by the quantitative Fuchs method [30].



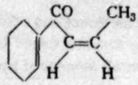
(IV) (V) (VI)

The treatment of dienone (VI) with 2,4-dinitrophenylhydrazine hydrochloride immediately gave a precipitate of mixed 2,4-dinitrophenylhydrazones, from which by fractional crystallization two isomers with m.p. 168-169° (A) and with m.p. 189-190° (B) were isolated in the ratio of approximately 10 : 1. Both isomers have the same absorption maximum in the ultraviolet region, equal to $\lambda_{max.}$ 373 mμ, characteristic for hydrazones with two conjugated double bonds, and not having a free vinyl group [31].

These results show that the obtained dienone (VI) represents a mixture of two geometric isomers with a predominance, in all probability, of the trans-isomer (VI A).



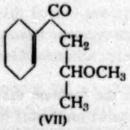
2,4-Dinitrophenylhydrazone, m.p. 168-169°



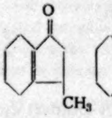
2,4-Dinitrophenylhydrazone, m.p. 189-190°

A similar geometric isomerism of α,β-unsaturated ketones on some simpler examples was recently described in the literature [32].

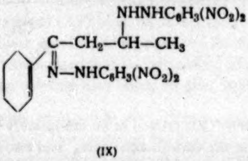
The mother liquor from the isolation of the hydrazones of dienone (VI) also contained a small amount of the 2,4-dinitrophenylhydrazone of 1-methyl-4,5,6,7-tetrahydroindan-3-one (VIII) with m.p. 246-247° and the product of the addition of two molecules of 2,4-dinitrophenylhydrazine to dienone (VI) with m.p. 250-251° (IX).



(VII)



(VIII)



(IX)

The hydration of vinyl-Δ^1-cyclohexenylacetylene (IV) in the presence of mercury sulfate, but without sulfuric acid, for 10 minutes at 65-72° (Expt. 3) also gave dienone (VI) with a small amount of the starting dienyne (IV). After distillation through a column the dienone (VI) has the same constants as the preceding, and gave the 2,4-dinitrophenylhydrazones (A) and (B) in a 3 : 1 ratio.

The cleavage of methanol from methoxy ketone (VII) by means of p-toluenesulfonic acid gave a mixture of the geometric isomers of dienone (VI), which gave the 2,4-dinitrophenylhydrazones (A) and (B) in an approximately 1 : 1 ratio. The ozonization of this dienone gave adipic acid and a mixture of formic and acetic acids in nearly equal amounts (53 and 47 %, respectively).

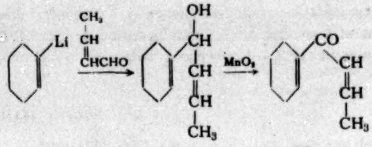
Attempting to avoid the isomerization of allyl-Δ^1-cyclohexenyl ketone (V), we ran the hydration of dienyne (IV) without sulfuric acid in an extremely short time (heating at 65-70° for several minutes). Thus, for example, hydration for 2 minutes at 65-70° without sulfuric acid (Expt. 4) gave a small amount of the dienone, in its constants somewhat different from those described above. Treatment of this dienone with 2,4-dinitrophenylhydrazine gave as the main product a third isomeric hydrazone (C) with m.p. 157-158°. However, its absorption maximum in the ultraviolet region ($\lambda_{max.}$ 373 mμ) proved to be completely identical with that of the preceding 2,4-dinitrophenylhydrazones (A) and (B). The mixed melting point of hydrazones (A) and (C) was 158-162°. Assuming the presence of polymorphic modification in this case, we ran their mutual recrystallization, but here we also obtained a mixture with m.p. 153-162°. When kept for a year the melting point of hydrazone (C) did not change. This hydrazone was also isolated by us in other experiments, and also from the first fractions in the distillation of dienone (VI).

As a result, the hydration of vinyl-Δ^1-cyclohexenylacetylene (IV) under milder conditions gave a third isomeric dienone with a m.p. of 157-158° for its 2,4-dinitrophenylhydrazone, which possibly represents the primary reaction product, i.e., allyl-Δ^1-cyclohexenyl ketone (V), under the experimental conditions isomerizing with extraordinary ease into propenyl-Δ^1-cyclohexenyl ketone (VI). However, the absence of a difference in the ultraviolet absorption spectra of the 2,4-dinitrophenylhydrazones of these dienones makes it necessary to synthesize allyl-Δ^1-cyclohexenyl ketone (V) by other methods, which would make it possible to definitely say whether it was formed in the hydration of vinyl-Δ^1-cyclohexenylacetylene (IV).

The heating of the 2,4-dinitrophenylhydrazones (A) and (B) in methanol solution in the presence of hydrochloric acid yields the hydrazone of methoxy ketone (VII). The addition of methanol and ethanol to the 2,4-dinitrophenylhydrazones (A) and (B) also occurs under the conditions of their formation, i.e., at room temperature.

The fact that methanol and ethanol add in the preparation of the 2,4-dinitrophenylhydrazones of α,β-unsaturated ketones is also mentioned in the literature [33]. The original dienone (VI) also easily adds methanol when heated with a small amount of hydrochloric acid.

For the conclusive identification of propenyl-Δ^1-cyclohexenyl ketone (VI) we specially synthesized it by the scheme proposed by Braude [34]

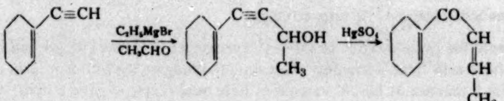


(X) (VI)

The synthetic dienone (VI) proved to be completely identical with the dienone that we obtained in the hydration of dienyne (IV) under various conditions, and also in the cleavage of methanol from methoxy ketone (VII). The 2,4-dinitrophenylhydrazones (A) and (B) obtained (in a 3 : 1 ratio) from the synthetic dienone melted at 168-169° and 189-190°, and did not depress the melting point when mixed with the above described specimens. The hydrazone with m.p. 152°, isolated by Braude, is apparently a mixture of hydrazones (A) and (B).

As a result, by three independent methods—ozonization, absorption spectra and special synthesis—it was rigidly established that the hydration of vinyl-Δ^1-cyclohexenylacetylene (IV) yields not allyl-Δ^1-cyclohexenyl ketone (V), but instead its isomer propenyl-Δ^1-cyclohexenyl ketone (VI).

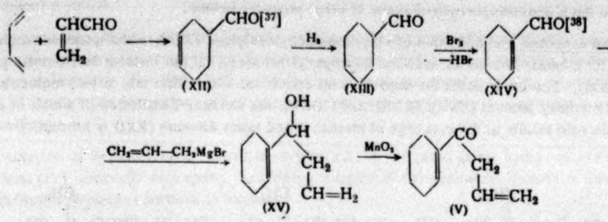
We also attempted to obtain this dienone by the isomerization of the vinylacetylene carbinol (XI), using the method developed earlier in our laboratory [35].



(XI) (VI)

The reaction of cyclohexenylacetylenemagnesium bromide with acetaldehyde gave the earlier described carbinol (XI) [36] in 64% yield. However, its isomerization under the influence of mercury salts (mercury sulfate in acetone or the Nieuwland catalyst in isopropyl alcohol) permits obtaining in high yield only the cyclic ketone (VIII), while dienone (VI) cannot be isolated under these conditions.

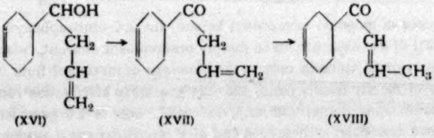
The direct synthesis of allyl-Δ^1-cyclohexenyl ketone (V) seemed of especial interest to us, which we attempted to accomplish by the following scheme



The reaction of allylmagnesium bromide with Δ^1-tetrahydrobenzaldehyde (XIV) by the method of Yavorsky and Gilman [39] gave us allyl-Δ^1-cyclohexenylcarbinol (XV) in about 80% yield. However, an attempt to oxidize the carbinol with freshly precipitated manganese dioxide, as is described for the propenyl-Δ^1-cyclohexenylcarbinol (X), proved unsuccessful. Here the starting carbinol was recovered almost completely. Oxidation of carbinol (XV) with chromic mixture in dioxane solution also failed to give legible results.

In a similar manner the reaction of allylmagnesium bromide with Δ^3-tetrahydrobenzaldehyde (XII) gave allyl-Δ^3-cyclohexenylcarbinol (XVI) in 85 % yield, which also could not be oxidized with manganese dioxide, even when boiled in petroleum ether for 6 hours. The oxidation of carbinol (XVI) with chromic mixture in dioxane solution at 10-15° gave a mixture of ketones (XVII and XVIII), from which we were able to isolate the corresponding 2,4-dinitrophenylhydrazones: one, with m.p. 83-84°, $\lambda_{max.}$ 346 mμ, $\epsilon_{max.}$ 18,000, corresponds to dienone (XVII) with two isolated double bonds, and the second, with m.p. 125-126°, $\lambda_{max.}$ 359 mμ, $\epsilon_{max.}$ 19,000, corresponds to dienone (XVIII) with one conjugated double bond.

As a result, in the oxidation of carbinol (XVI) with chromic mixture the formed allyl-Δ^3-cyclohexenyl ketone (XVII) is partially isomerized to propenyl-Δ^3-cyclohexenyl ketone (XVIII).

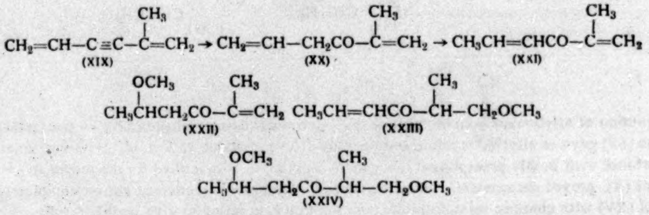


To study behavior of allyl and propenyl ketones we repeated the synthesis of ethyl allyl ketone by reacting allylzinc bromide with propionitrile in anhydrous benzene solution [15]. However, here together with the ethyl allyl ketone we also obtained the isomeric ethyl propenyl ketone in a 1:1 ratio.

$$CH_3CH_2CN \xrightarrow{Zn+CH_2=CHCH_2Br} CH_3CH_2COCH_2CH{=}CH_2 \rightarrow CH_3CH_2COCH{=}CHCH_3$$

When we attempted to distill the ethyl allyl ketone through a glass-packed column with an efficiency of 18 theoretical plates it almost completely isomerized into ethyl propenyl ketone. The 2,4-dinitrophenylhydrazone of the ethyl allyl ketone, obtained under ice-cooling, melted at 118-119° and had $\lambda_{max.}$ 344 mμ (in isooctane), which corresponds to the hydrazone with an isolated double bond. Under the usual conditions the ethyl propenyl ketone gave the 2,4-dinitrophenylhydrazone with m.p. 141-142°; $\lambda_{max.}$ 363 mμ (in isooctane), characteristic for the hydrazone with a conjugated double bond. In addition, from the mother liquor we isolated a hydrazone with m.p. 168°, from its analysis corresponding to the addition product of a molecule of 2,4-dinitrophenylhydrazine to the 2,4-dinitrophenylhydrazone of ethyl propenyl ketone.

As was to be expected, the hydration of vinylisopropenylacetylene (XIX), which proceeds more slowly and was run at 60-65° for 8 hours, also yields not allyl isopropenyl ketone (XX), but instead the isomeric propenyl isopropenyl ketone (XXI). The latter under the experimental conditions adds either one or two molecules of methanol and gives the methoxy ketones (XXII), (XXIII) and (XXIV), the vacuum-distillation of which in the presence of p-toluenesulfonic acid results in the cleavage of methanol and again dienone (XXI) is formed.

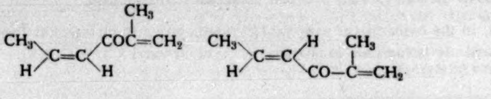


$$\underset{(XIX)}{CH_2{=}CH{-}C{\equiv}C{-}\overset{CH_3}{\overset{|}{C}}{=}CH_2} \rightarrow \underset{(XX)}{CH_2{=}CH{-}CH_2CO{-}\overset{CH_3}{\overset{|}{C}}{=}CH_2} \rightarrow \underset{(XXI)}{CH_3CH{=}CHCO{-}\overset{CH_3}{\overset{|}{C}}{=}CH_2}$$

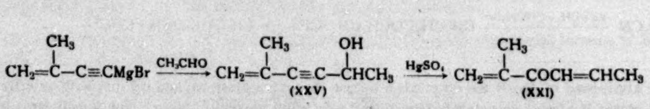
$$\underset{(XXII)}{CH_3\overset{OCH_3}{\overset{|}{C}}HCH_2CO{-}\overset{CH_3}{\overset{|}{C}}{=}CH_2} \quad \underset{(XXIII)}{CH_3CH{=}CHCO{-}\overset{CH_3}{\overset{|}{C}}H{-}CH_2OCH_3}$$

$$\underset{(XXIV)}{CH_3\overset{OCH_3}{\overset{|}{C}}H{-}CH_2CO{-}\overset{CH_3}{\overset{|}{C}}H{-}CH_2OCH_3}$$

Apparently, propenyl isopropenyl ketone (XXI) is also formed as two geometric isomers with different physical constants, which give the 2,4-dinitrophenylhydrazones with m.p. 123-124° and 157-158°, having the same absorption spectrum $\lambda_{max.}$ 361-362 mμ (in isooctane), characteristic for the ketones with two conjugated double bonds and one unsubstituted vinyl group [31]:



The stable trans-isomer of propenyl isopropenyl ketone, the 2,4-dinitrophenylhydrazone of which melts at 157-158° was formed in all of the experiments in sharply predominant amount, whereas we were able to isolate the unstable cis-isomer in small amounts only in the cleavage of methanol from methoxy ketones (XXII-XXIV). The dinitrophenylhydrazone of the cis-isomer (m.p. 123-124°), already after either recrystallization or long standing, is converted into the stable trans-isomer with m.p. 157-158°. Both of the geometric isomers of dienone (XXI) when hydrogenated absorb two molecules of hydrogen and give propyl isopropyl ketone, and when reacted with phosphoric acid they cyclicize to 1,3-dimethyl-Δ^1-cyclopenten-5-one. When heated in the presence of iodine the low-boiling cis-isomer of propenyl isopropenyl ketone (XXI) is isomerized to the trans-isomer. The structure of the above described propenyl isopropenyl ketone (XXI) was confirmed by its synthesis by another independent method. The reaction of isopropenylacetylenemagnesium bromide with acetaldehyde gave the earlier described vinylacetylenic alcohol (XXV) [35] in 69% yield, the isomerization of which under the influence of mercury sulfate in dry acetone gave propenyl isopropenyl ketone (XXI), completely identical with the preceding:

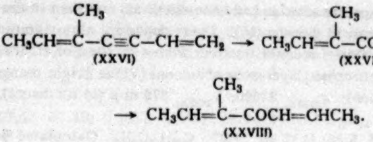


$$CH_2{=}\overset{CH_3}{\overset{|}{C}}{-}C{\equiv}CMgBr \xrightarrow{CH_3CHO} \underset{(XXV)}{CH_2{=}\overset{CH_3}{\overset{|}{C}}{-}C{\equiv}C{-}\overset{OH}{\overset{|}{C}}HCH_3} \xrightarrow{HgSO_4} \underset{(XXI)}{CH_2{=}\overset{CH_3}{\overset{|}{C}}{-}COCH{=}CHCH_3}$$

Here a substantial amount of 1,3-dimethyl-Δ^1-cyclopenten-5-one is also formed, i.e., the cyclization product of dienone (XXI). However, an attempt to accomplish the cyclization of dienone (XXI) under these conditions proved unsuccessful. For the most part the dienone was recovered unchanged. Consequently, in this case the cyclization of dienone (XXI) apparently occurs at the moment of its formation. It should be mentioned that this cyclization is also not observed when the hydration of dienyne (XIX) is run in the presence of mercury sulfate in methanol solution.

Striving to create milder conditions, which would exclude the isomerization of allyl isopropenyl ketone during the hydration process, we attempted to hydrate vinylisopropenylacetylene (XIX) in acetic acid in the presence of mercury acetate. However, here we were unable to obtain positive results, since under the mild conditions all of the dienyne was recovered unchanged, while under more drastic conditions it was almost completely polymerized.

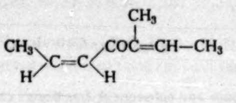
The hydration of 5-methyl-1,5-heptadien-3-yne (XXVI), the same as the hydration of vinyl-Δ^1-cyclohexenylacetylene (IV), proceeds very easily, and here a mixture of the geometric isomers of dienone (XXVIII) with sharply different physical constants is formed:



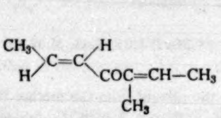
$$\underset{(XXVI)}{CH_3CH{=}\overset{CH_3}{\overset{|}{C}}{-}C{\equiv}C{-}CH{=}CH_2} \rightarrow \underset{(XXVII)}{CH_3CH{=}\overset{CH_3}{\overset{|}{C}}{-}COCH_2CH{=}CH_2}$$

$$\rightarrow \underset{(XXVIII)}{CH_3CH{=}\overset{CH_3}{\overset{|}{C}}{-}COCH{=}CHCH_3}.$$

In this case also we were unable to prove the presence of the allyl dienone (XXVII). By distilling the obtained mixture of isomeric dienones (XXVII) through an efficient column we were able to obtain its separation into the individual cis- and trans-isomers of the following structure:



cis-



trans-

Isomerization at the second double bond, found in the molecule from the original dienyne, appears less probable in the given case. The low-boiling cis-isomer when heated to 170-180° (preferably in the presence of iodine) is easily isomerized to the trans-isomer, having a much higher melting point and index of refraction. Under the usual conditions both of the isomeric dienones give the same 2,4-dinitrophenylhydrazone, having its absorption maximum in the ultraviolet region at 371 m μ (in isooctane), characteristic for dienones with two conjugated double bonds.

As a result, the hydration of dienynes (I) under the influence of mercury sulfate in aqueous methanol solutions leads to the formation of the corresponding dienones (III) with two conjugated double bonds. In this connection, in not a single case were we able to fully prove the presence of the allyl form of the dienones (substituted vinyl allyl ketones, II).

EXPERIMENTAL

Hydration of vinyl-Δ^1-cyclohexenylacetylene (IV) [27]. Expt. 1. A mixture of 118 g of dienyne (IV) (b.p. 79-80° at 9 mm, n_D^{20} 1.5440), 300 ml of 80 % methanol, 12 g of mercury sulfate and 2 g of concentrated sulfuric acid was stirred for 30 minutes at 65-67°. The solution was filtered, 80-100 ml of methanol was vacuum-distilled at a bath temperature not exceeding 50°, the residue was diluted with water (50 ml), neutralized with soda, and extracted with ether. After drying over sodium sulfate the ether was distilled off, while the residue was distilled from a Favorsky flask. We obtained 115 g of substance with b.p. 107-125° (7 mm) and 25 g of tarry residue. Redistillation gave the following fractions: 1st, b.p. 94-103° (8 mm), n_D^{20} 1.5050; 1 g; 2nd b.p. 104-106° (8 mm), n_D^{20} 1.5118, 45 g; 3rd. b.p. 107-109° (8 mm), n_D^{20} 1.5113, 40 g; 4th, b.p. 94-102° (4 mm), n_D^{20} 1.5060, 12 g; 5th, b.p. 103-107° (4 mm), n_D^{20} 1.4950, 13 g.

The second and third fractions represent not completely pure propenyl-Δ^1-cyclohexenyl ketone (VI); the fourth and fifth fractions are a mixture of dienone (VI) and β-methoxypropyl-Δ^1-cyclohexenyl ketone (VII).

The second fraction was distilled further in the presence of pyrogallol through a column packed with glass helices and having an efficiency of 25 theoretical plates. Here the pure propenyl-Δ^1-cyclohexenyl ketone (VI) was isolated as a yellowish liquid:

B.p. 132.5-133° (24 mm), n_D^{20} 1.5165, d_D^{20} 0.9769, MR_D 46.43, calc. 45.26; $\lambda_{max.}$ 254, 330 mμ (in methanol).

Preparation of the 2,4-dinitrophenylhydrazones of propenyl-Δ^1-cyclohexenyl ketone (VI). A mixture of 2.6 g of 2,4-dinitrophenylhydrazine, 2.4 ml of concentrated hydrochloric acid, 120 ml of ethanol and 15 ml of dioxane was boiled under reflux until complete solution had been obtained, and then to the cooled solution after filtration was added 2 g of the above described dienone (VI). There deposited almost immediately 1.9 g of crystals with m.p. 145-160°, from which after 3 recrystallizations from a mixture of ethanol and ethyl acetate (1: 1) we isolated 1 g of the pure 2,4-dinitrophenylhydrazone of dienone (VI) as bright orange prisms with m.p. 168-169° (A); $\lambda_{max.}$ 373 mμ (in isooctane); $\epsilon_{max.}$ 21000; $\lambda_{max.}$ 379 mμ (in methanol).

Found %: C 58.20, 58.15; H 5.55, 5.55; N 17.00, 17.07. $C_{16}H_{18}O_4N_4$. Calculated %: C 58.1; H 5.5; N 16.97.

In 4 days there deposited in small portions from the mother liquor still another 190 mg of crystals with m.p. 160-180°, which after 2 recrystallizations from a mixture of ethanol and ethyl acetate gave about 100 mg of a second 2,4-dinitrophenylhydrazone as dark-orange prisms with m.p. 189-190° (B); $\lambda_{max.}$ 373 mμ (in isooctane), $\epsilon_{max.}$ 381 mμ (in methanol).

Found %: C 57.83, 57.96; H 5.35, 5.43; N 17.07, 17.07. $C_{16}H_{18}O_4N_4$. Calculated %: C 58.1; H 5.5; N 16.97.

Removal of part of the solvent from the mother liquor and subsequent fractional crystallization gave 15 mg of bright-yellow crystals with m.p. 250-251° (with decompn.).

Found %: C 49.29, 49.31; H 4.79, 4.54; N 21.30. $C_{22}H_{24}O_8N_8$. Calculated %: C 50.00; H 4.53; N 21.20.

As can be seen from the analysis, this substance (IX) corresponds to the addition product of 2,4-dinitrophenylhydrazine to the dinitrophenylhydrazones (A) and (B). From the mother liquor residues by recrystallization from an ethanol-benzene (10: 1) mixture we also isolated 15 mg of the 2,4-dinitrophenylhydrazone of the cyclic ketone (VIII) with m.p. 246-247°, failing to give a melting point depression with the authentic specimen; $\lambda_{max.}$ 357, 376, 392 mμ (in isooctane); $\epsilon_{max.}$ 21,000.

Found %: C 58.05, 58.19; H 5.44, 5.35; N 16.95, 16.88. $C_{16}H_{18}O_4N_4$. Calculated %: C 58.1; H 5.5; N 16.97.

Expt. 2. A mixture of 50 g of dienyne (IV), 130 g of 80% methanol and 5 g of mercury sulfate was stirred for 5 minutes with gradual elevation of the water bath temperature from 20 to 60° (the temperature inside the liquid was 5° lower). Then the stirring at 63-65° was continued for another 10 minutes (the temperature inside the liquid was 2-3° higher and did not drop when the external heating was stopped). The reaction mixture turned yellow, and the catalyst was reduced. The stratified liquid was neutralized with soda, extracted with ether, and the ether extract was dried over sodium sulfate. After distilling off the ether and methanol the residue was distilled from a Favorsky flask. We obtained 25 g of the starting dienyne and 17 g of a substance with b.p. 90-105° at 6 mm, n_D^{20} 1.5210. From this fraction after 3 distillations we obtained 8 g of dienone (VI) with b.p. 107-109° (9 mm), n_D^{20} 1.5180.

From 1.9 g of this dienone we obtained the 2,4-dinitrophenylhydrazones by the above described method. The fraction of crystals that deposited immediately, in an amount of 1.75 g and with m.p. 145-160°, after repeated recrystallization from a mixture of ethanol and ethyl acetate, and then from a mixture of ethanol and benzene, gave 2,4-dinitrophenylhydrazone (C) as bright-orange crystals with m.p. 157-158°, which failed to change after chromatographing on aluminum oxide (elution with benzene), and also when stored for a year; $\lambda_{max.}$ 373 mμ (in isooctane); $\epsilon_{max.}$ 2100, $\lambda_{max.}$ 379 mμ (in methanol).

Found %: C 58.25, 58.05; H 5.45, 5.51; N 16.98, 16.88. $C_{16}H_{18}O_4N_4$. Calculated %: C 58.1; H 5.5; N 16.97.

Its mixture with isomer (A) (m.p. 168-169°) melted at 158-162°.

The next day 250 mg of crystals with m.p. 185° deposited from the mother liquor, from which 2,4-dinitrophenylhydrazone (B) with m.p. 188-189° was isolated (from a mixture of ethanol and ethyl acetate). Its mixed melting point with hydrazone (B) (m.p. 189-190°), isolated in Expt. 1, was not depressed.

Removal of the solvent from the mother liquor gave (after several recrystallizations from ethanol) about 100 mg of dark-red crystals of the 2,4-dinitrophenylhydrazone of β-ethoxypropyl-Δ^1-cyclohexenyl ketone with m.p. 126-127°, formed as the result of the addition of ethanol to dinitrophenylhydrazones (A) and (B); $\lambda_{max.}$ 371 mμ (in isooctane), $\epsilon_{max.}$ 18,000.

Found %: C 57.45, 57.19; H 6.57, 6.38; N 14.74, 14.88. $C_{18}H_{24}O_5N_4$. Calculated %: C 57.43, H 6.42; N 14.88.

The preparation of the 2,4-dinitrophenylhydrazone of dienone (VI) in methyl alcohol solution gave, together with hydrazones (B) and (C), also the 2,4-dinitrophenylhydrazone of β-methoxypropyl-Δ^1-cyclohexenyl ketone (VII) with m.p. 118-119° (from ethanol); $\lambda_{max.}$ 370 mμ (in isooctane), $\epsilon_{max.}$ 21,000.

Found %: C 56.35, 56.39; H 6.03, 6.09. $C_{17}H_{22}O_5N_4$. Calculated %: C 56.53; H 6.01.

This 2,4-dinitrophenylhydrazone (m.p. 118-119°) is also obtained by the direct addition of methanol to the 2,4-dinitrophenylhydrazones (A) and (B) with heating in the presence of a small amount of concentrated hydrochloric acid.

Mutual recrystallization of hydrazones (A) and (C). A mixture of 11.6 mg of hydrazone (A) (m.p. 168-169°) and 11.4 mg of hydrazone (C) (m.p. 157-158°) was boiled in a mixture of 3 ml of ethanol and 2 ml of benzene for 10 minutes. After cooling the solution we isolated three fractions of crystals with m.p. 161-163°, 156-162° and 153-155°, representing a mixture of the starting substances.

Expt. 3. To a solution of 75 g of dienyne (IV) in 170 g of 80% methanol, heated to 65°, was added vigorous stirring 7 g of mercury sulfate. In 5 minutes the temperature in the flask was raised to 72°, and it failed to drop when external heating was stopped. In 10 minutes the reaction mixture was cooled to 40°, filtered, washed with soda solution, the product extracted with ether, dried over sodium sulfate, and vacuum-distilled. The following fractions were obtained (at 7 mm): 1st, b.p. 79-103°, n_D^{20} 1.5260, 18.5 g; 2nd, b.p. 103-108°, n_D^{20} 1.5155, 46.0 g; tarry residue 7.5 g.

After being kept for 4 months in a nitrogen atmosphere and in the presence of pyrogallol the second fraction was redistilled through a column with an efficiency of 18 theoretical plates, and here 20 g of dienone (VI) was isolated:

B.p. 130-131° (24 mm), n_D^{20} 1.5190, d_D^{20} 0.9775, MR_D 46.43; calcd. 45.26; $\lambda_{max.}$ 330 mμ (in methanol).

From this dienone we obtained the 2,4-dinitrophenylhydrazones (A) (m.p. 168-169°) and (B) (m.p. 189-190°) in a 3 : 1 ratio.

Expt. 4. A mixture of 100 g of dienyne (IV), 250 g of 80 % methanol and 10 g of mercury sulfate was stirred with slow elevation of the water bath temperature from 20 to 70° in 20 minutes. External evidence of the start of reaction under these conditions was not observed. The reaction liquid was stirred a total of 2 minutes at a bath temperature of 70°. After cooling, the methanol was distilled off under slight vacuum in 2 hours (bath temperature 35-37°). The residue was extracted with ether (the water layer was acid), the ether extract washed with soda solution, and dried over sodium sulfate. The first distillation gave 80 g of starting dienyne and 5.5 g of a substance with b.p. 84-89° (3 mm), n_D^{20} 1.5170, from which after 4 distillations (without pyrogallol) using a Favorsky flask we isolated 2 g of dienone (V ?):

B.p. 85-85.5° (3 mm), n_D^{20} 1.5105, d_D^{20} 0.9715, MR_D 46.0; calcd. 45.26.

From 100 mg of this dienone we obtained 80 mg of 2,4-dinitrophenylhydrazone (C) with m.p. 157-158°, failing to give a melting point depression with the above described specimen.

When distilled in the presence of pyrogallol the constants of the dienone failed to change. The distillation of this dienone (0.9 g), after being kept in the presence of pyrogallol (13 mg) for 20 days, gave a mixture of substances, from which after repeated fractional crystallization we isolated the 2,4-dinitrophenylhydrazones (B) (m.p. 182-184°) and (C) (m.p. 155-156°).

The described 2,4-dinitrophenylhydrazone (C) (m.p. 157-158°) is always obtained from the first low-boiling fractions, isolated in the distillation of the products of the hydration of dienyne (IV) under mild conditions.

Attempted isomerization of dienone (V ?). A mixture of 0.35 g of the dienone (b.p. 85-85.5° at 3 mm, n_D^{20} 1.5105), 1 g of 85% methanol and 0.02 g of mercury sulfate was heated for 15 minutes at 60-65°. Here the catalyst was not reduced, and only when the temperature was raised to 70° did it reduce in 1-2 minutes. The solution reacted acid. The reaction product was neutralized with soda, extracted with ether, dried over sodium sulfate, and vacuum-distilled. Here 0.2 g of substance (n_D^{19} 1.5105) was isolated, from which the 2,4-dinitrophenylhydrazone (C) with m.p. 155-156° was obtained. A small amount of bright-yellow crystals of substance (IX) with m.p. 250° was also isolated from the mother liquor, formed as the result of the addition of 2,4-dinitrophenylhydrazine to hydrazones (A) and (B).

Ozonization of propenyl-Δ^1-cyclohexenyl ketone (VI). Four grams of dienone (VI), obtained in Expt. 1 (b.p. 132.5-133° at 24 mm, n_D^{20} 1.5165), was dissolved in 55 ml of dry chloroform and then ozonized oxygen was passed through the solution at a rate of 3 liter/hour (the ozone concentration was 6%). After adding 20 ml of water the ozonide was stirred for 1 hour at 55-60°, 10 ml of 10% hydrogen peroxide was added, and the stirring at this temperature was continued for another 3 hours. The resulting acids were neutralized with soda (4.7 g), and the neutral products were extracted with ether, but hardly any proved to be present (the residue weighed about 0.5 g). Using the calomel method the water solution was shown to contain 66% formic acid. The water was vacuum-distilled from the solution of salts, the residue was treated with concentrated hydrochloric acid (20 ml), the organic acids were thoroughly extracted with ether, and the ether solution was dried over sodium sulfate. The ether was distilled off, and distillation under slight vacuum (100-150 mm) gave 0.5 g of volatile acids, in which the presence of acetic acid was shown by the cacodyl test. The crystalline residue, weighing 2.2 g, was recrystallized from water. Here we obtained 1.5 g of adipic acid with m.p. 149-150°, failing to give a melting point depression with the authentic specimen.

By the Fuchs method the volatile acids were found to contain 54% formic acid and 46% acetic acid.

Cleavage of methanol from β-methoxypropyl-Δ^1-cyclohexenyl ketone (VII). A mixture of 50 mg* of methoxy ketone (VII) (b.p. 112-114° at 7 mm, n_D^{20} 1.4870) and 0.16 g of p-toluenesulfonic acid was heated at 100° and a vacuum of 45 mm for 45 minutes. After removal of the methanol the residue was vacuum-distilled. We obtained 37 g of substance, the distillation of which through a column with an efficiency of 25 theoretical plates gave 24 g of dienone (VI):

B.p. 133-135° (25 mm), n_D^{20} 1.5177, d_D^{20} 0.9800, MR_D 46.4; calcd. 45.26.

The obtained dienone gave a mixture of the 2,4-dinitrophenylhydrazones (A) (m.p. 168-169°), (B) (m.p. 189-190°) and of the cyclic ketone (VIII) (m.p. 246-247°) in the ratio 4 : 4 : 1. The mixed melting point with authentic specimens was not depressed.

The ozonization of 4 g of this dienone under the above described conditions gave 0.7 g of volatile acids

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* As in original – Publisher's note.

(b.p. 102-109°) and 1.2 g of adipic acid with m.p. 150-151°. By the calomel method the total solution was found to contain 86.5% formic acid. The quantitative determination of formic and acetic acids in the volatile acids by the Fuchs method revealed the presence of 52% formic and 47% acetic acid in the mixture.

Addition of methanol to propenyl-Δ^1-cyclohexenyl ketone in the presence of hydrochloric acid. A mixture of 5 g of dienone (VI) (b.p. 106-108° at 8 mm, n_D^{20} 1.5150), 75 g of 93% methanol and 2 ml of concentrated hydrochloric acid was stirred for 4 hours at 80°. After suitable treatment we isolated 4.5 g of substance with b.p. 121-123° (9 mm), n_D^{20} 1.4920, from which we obtained the 2,4-dinitrophenylhydrazones of the cyclic ketone (VIII) with m.p. 242-243° and of the methoxy ketone (VII) with m.p. 116-117° in a 1: 1 ratio.

Preparation of propenyl-Δ^1-cyclohexenylcarbinol (X). To a suspension of 7.8 g of lithium metal in 1 liter of absolute ether was added in drops with stirring, in 3 hours (in a nitrogen atmosphere), a solution of 61 g of Δ^1-cyclohexenyl chloride (b.p. 63° at 49 mm, n_D^{20} 1.4815) [34,41] in 30 ml of absolute ether. The next day 37 g of crotonaldehyde was added in 1.5 hours with constant stirring and ice-cooling to the cyclohexenyllithium prepared in this manner. Then the reaction mixture was stirred in a nitrogen stream for 7 hours, and then the next day for another 6 hours at room temperature. The product was treated with 500 ml NH_4Cl solution and the ether solution was dried over sodium sulfate and potash. After removal of the ether the residue was vacuum-distilled twice. We obtained 21 g of carbinol (X) with b.p. 85-87° (3 mm), n_D^{20} 1.5008. Tarry residue, 25 g [42, 14].

Oxidation of propenyl-Δ^1-cyclohexenylcarbinol (X). A mixture of 17.7 g of carbinol (X) in 1250 ml of dry petroleum ether (b.p. 40-65°) and 126 g of freshly precipitated dry manganese dioxide was shaken in a nitrogen atmosphere at room temperature for 34 hours. After filtration and removal of the solvent the reaction product was vacuum-distilled. We obtained 13.5 g of substance with b.p. 103-110° (7 mm), n_D^{20} 1.5165, the distillation of which through a column with an efficiency of 18 theoretical plates gave 6 g of propenyl-Δ^1-cyclohexenyl ketone (VI) with b.p. 131-131.5° and 24 mm, n_D^{20} 1.5195, d_4^{20} 0.9755.

We also isolated 3 g of substance with b.p. 86-90° (12 mm), n_D^{25} 1.5545, apparently being the dehydration product of the original carbinol (X).

Found %: C 86.34, 86.04; H 10.30, 10.40. $C_{10}H_{14}$. Calculated %: C 89.55; H 10.45.

The dienone (VI) obtained in this manner gave a mixture of 2,4-dinitrophenylhydrazones (A) (m.p. 168-169°) and (B) (m.p. 189-190°) in a 3: 1 ratio. The mixed melting point with the above described specimens was not depressed. The mother liquor was shown to contain a small amount of the 2,4-dinitrophenylhydrazone of β-ethoxypropyl-Δ^1-cyclohexenyl ketone with m.p. 125-126°, also failing to give a melting point depression with the above described specimens, and formed by the addition of ethyl alcohol to the 2,4-dinitrophenylhydrazone of dienone (VI) during its preparation.

According to the data of Braude, propenyl-Δ^1-cyclohexenyl ketone has the following constants: b.p. 64-65° (0.3 mm), n_D^{20} 1.5164, $\lambda_{max.}$ 257, 328 mμ (in ethanol), $\epsilon_{max.}$ 14600, melting point of the 2,4-dinitrophenylhydrazone 152°.

When heated with phosphoric acid the obtained dienone (VI) is cyclized in high yield to 1-methyl-4,5,6,7-tetrahydroindan-3-one (VIII) [27].

Synthesis of allyl-Δ^3-cyclohexenylcarbinol (XVI). The starting Δ^3-tetrahydrobenzaldehyde (XII) was obtained by the earlier described method [37] by the condensation of divinyl with acrolein and had the following constants: b.p. 52-53° (11 mm), n_D^{20} 1.4728, melting point of the 2,4-dinitrophenylhydrazone 176-177°, $\lambda_{max.}$ 339 mμ (in methanol); $\epsilon_{max.}$ 19000.

To 31 g of magnesium metal covered with 350 ml of absolute ether was added 10 g of allyl bromide and an iodine crystal. After reaction had started a mixture of 55 g of aldehyde (XII) and 80 g of allyl bromide in 400 ml of absolute ether was added in 6 hours with constant stirring. Here the temperature rose from 20 to 35°. Then the stirring was maintained for another hour. The reaction mixture was decomposed with ice water (250 ml), the ether layer was washed with water, and then dried over sodium sulfate. After distilling off the ether the residue was vacuum-distilled twice from a Favorsky flask. We obtained 65 g (85%) of allyl-Δ^3-cyclohexenylcarbinol (XVI) as a colorless viscid liquid with a specific odor and b.p. 96-97° (7 mm), n_D^{20} 1.4940, d_4^{20} 0.9546.

Found %: C 78.78, 78.63; H 10.56, 10.59. $C_{10}H_{16}O$. Calculated %: C 78.88; H 10.52.

The hydrogenation of 6 g of carbinol (XVI) gave 5.6 g of propylcyclohexylcarbinol:

B.p. 105° (13 mm, n_D^{20} 1.4655, d_4^{20} 0.9067, MR_D 47.7; calcd. 47.7.
Found %: C 76.76; H 10.89. $C_{10}H_{20}O$. Calculated %: C 76.91; H 10.82.

The oxidation of 3.5 g of propylcyclohexylcarbinol with potassium dichromate in acetic acid gave 2.5 g of propyl cyclohexyl ketone with b.p. 92.5-93° (12 mm), n_D^{20} 1.4545, the semicarbazone of which melted at 154-155° (from methanol) and failed to give a melting point depression with the authentic specimen [27].

Oxidation of allyl-Δ^3-cyclohexenylcarbinol (XVI). To a solution of 9.5 g of carbinol (XVI) (b.p. 96-97° at 7 mm, n_D^{20} 1.4940) in 200 ml of dioxane was added in 4 hours at 5-10° a solution of 5.9 g of potassium dichromate in 180 ml of 2N sulfuric acid, after which the reaction mixture was stirred for another hour at 10-15°. The reaction products were neutralized with soda, extracted with ether, and the ether extract was dried over sodium sulfate. After distilling off the ether the residue was distilled to give the following fractions (at 9 mm): 1st, b.p. 94-98°, n_D^{20} 1.4870, 2nd, b.p. 98-99°, n_D^{20} 1.4890, 3.0 g; 3rd, b.p. 100-104°, n_D^{20} 1.4930, 1.5 g.

From 300 mg of the first fraction we obtained 70 mg of the 2,4-dinitrophenylhydrazone of dienone (XVII) with m.p. 83-84° as bright-orange crystals; $\lambda_{max.}$ 346 mμ (from ethanol), $\epsilon_{max.}$ 18000.

Found %: C 58.07; H 5.44; N 18.08, 16.90. $C_{18}H_{18}O_4N_4$. Calculated %: C 58.1; H 5.5; N 16.97.

Removal of part of the solvent from the mother liquor gave about 20 mg of the 2,4-dinitrophenylhydrazone of dienone (XVIII) as dark-red crystals with m.p. 125-126° (from ethanol with ethyl acetate); $\lambda_{max.}$ 359 mμ (from ethanol), $\epsilon_{max.}$ 19000.

Found %: C 58.12, 57.97; H 5.55, 5.64; N 17.10, 16.99. $C_{18}H_{18}O_4N_4$. Calculated %: C 58.1; H 5.5; N 16.97.

When the 2,4-dinitrophenylhydrazone of the first fraction was prepared in methanol solution we isolated the 2,4-dinitrophenylhydrazone of β-methoxypropyl-Δ^3-cyclohexenyl ketone as bright-yellow needles with m.p. 73-75° (from ethanol), $\lambda_{max.}$ 346 mμ (from ethanol).

Found %: C 56.24, 56.27; H 6.23, 6.10; N 16.03. $C_{17}H_{22}O_5N_4$. Calculated %: C 56.35; H 6.07; N 15.6.

From the second fraction (3 g) we also obtained a mixture of the 2,4-dinitrophenylhydrazones of dienones (XVII) and (XVIII) with m.p. 60-120°.

We were unable to oxidize carbinol (XVI) by shaking it with manganese dioxide in absolute petroleum ether at room temperature (33 hours), or at 75-80° (6 hours), or with potassium dichromate in 1N sulfuric acid at 0°. Under these conditions the carbinol was recovered unchanged.

When the oxidation of carbinol (XVI) was attempted by the Oppenauer method we obtained a mixture of substances that was difficult to identify, from which we were able to isolate as the 2,4-dinitrophenylhydrazone with m.p. 150-151° (orange needle crystals) the condensation product of the cyclohexanone taken for reaction; $\lambda_{max.}$ 347 mμ (in isooctane).

Found %: C 60.18, 60.20; H 6.06, 6.17. $C_{18}H_{22}O_4N_4$. Calculated %: C 60.32; H 6.18.

From the first fraction of this mixture (b.p. 78-85° at 6 mm, n_D^{22} 1.4800) we isolated a 2,4-dinitrophenylhydrazone of unknown structure as dark-red crystals with m.p. 172-173° (from a mixture of ethanol and ethyl acetate), $\lambda_{max.}$ 362 mμ (in isooctane), $\epsilon_{max.}$ 17000.

Found %: C 56.55, 56.50; H 5.72, 5.76.

Attempted Isomerization of Δ^3-tetrahydrobenzaldehyde (XII) to Δ^1-tetrahydrobenzaldehyde (XIV). A mixture of 3.3 g of aldehyde (XII), 40 ml of benzene, 2 ml of concentrated hydrochloric acid and 2 ml of glacial acetic acid was heated for 1 hour at 100°. After neutralization and removal of the solvent by distillation the residue was vacuum-distilled. We obtained 2.5 g of the original aldehyde (XII) with b.p. 52-53° at 11 mm, n_D^{20} 1.4725.

With 7 hours of heating, together with the original aldehyde, we also isolated its crystalline trimer with m.p. 175-176° [37].

Hexahydrobenzaldehyde (XIII) [38] was obtained by the hydrogenation of Δ^3-tetrahydrobenzaldehyde (XII) in the presence of palladium on calcium carbonate and had the following constants: b.p. 62-63° at 25 mm, n_D^{20} 1.4512; the 2,4-dinitrophenylhydrazone melted at 172°; $\lambda_{max.}$ 338 mμ (in isooctane). The semicarbazone melted at 166-167°.

Δ^1-Tetrahydrobenzaldehyde (XIV) [38] was obtained by the bromination and dehydrobromination of hexahydrobenzaldehyde (XIII), and had the following constants: b.p. 51-52° at 5 mm, n_D^{20} 1.4910; the 2,4-dinitrophenylhydrazone melted at 219°, $\lambda_{max.}$ 362 mμ (in isooctane).

Synthesis of allyl-Δ^1-cyclohexenylcarbinol (XV). To a mixture of 6 g of magnesium metal, 2 g of allyl bromide and 100 ml of absolute ether was added with constant stirring in 3.5 hours a solution of 10 g of aldehyde (XIV) and 15 g of allyl bromide in 150 ml of absolute ether (here the temperature of the liquid rose to 34°). Then the stirring was continued for another hour. The reaction mixture was decomposed with ice water, the ether layer was washed with water, and then dried over sodium sulfate. After distilling off the ether the residue was vacuum-distilled. We obtained 10.5 g (75%) of allyl-Δ^1-cyclohexenylcarbinol (XV) as a colorless liquid with b.p. 97-98° (8 mm), n_D^{20} 1.4925, d_4^{20} 0.9495.

Found %: C 78.70, 78.55; H 10.50, 10.44. $C_{10}H_{16}O$. Calculated %: C 78.88; H 10.52.

Oxidation of allyl-Δ^1-cyclohexenylcarbinol (XV). To a solution of 5.0 g of carbinol (XV) in 100 ml of dioxane was added in 2 hours at 8-9° a solution of potassium dichromate in 200 ml of 2N sulfuric acid, after which stirring at 12-13° was continued for another hour. The reaction mixture was neutralized with soda, then extracted with ether, and the ether extract dried over sodium sulfate. After removal of the solvent the residue was vacuum-distilled. We obtained 0.9 g of substance with b.p. 87-97° at 7 mm, n_D^{20} 1.4765, and 2 g of substance with b.p. 98-100° at 7 mm, n_D^{20} 1.4915. From both fractions we obtained a small amount of the 2,4-dinitrophenylhydrazone as a dark-red powder with m.p. 218-219° (from a mixture of ethanol and ethyl acetate).

Found %: C 46.00, 45.70; H 3.82, 3.72.

Synthesis of ethyl allyl ketone [15]. To a mixture of 34 g of zinc, 29 g of propionitrile (b.p. 94-96°) and 100 ml of benzene was added with constant stirring and cooling (5-6°) 32 g of allyl bromide and an iodine crystal. The reaction did not begin in 5 hours. After adding another 33 g of allyl bromide the temperature was slowly raised to 22°. Stirring at this temperature was maintained for 5 hours. The reaction products were decomposed at first with ice, and then under cooling (the temperature of the liquid remained below 18°) with 20% sulfuric acid. The benzene solution was washed with water until neutral, the water layer was extracted with ether, the product neutralized with soda, and then dried over sodium sulfate. After distilling off the solvent the residue was distilled at atmospheric pressure. We obtained 18.5 g of a mixture of substances with b.p. 110-138°, from which by fractional distillation we isolated 10 g of ethyl allyl ketone and 6 g of ethyl propyl ketone. *

The constants of ethyl allyl ketone: b.p. 126-128° at atmospheric pressure, n_D^{20} 1.4235, d_4^{20} 0.8466, MR_D 25; calcd. 24.83; 2,4-dinitrophenylhydrazone was obtained under ice-cooling as orange crystals with m.p. 118-119° (from a mixture of ethanol and ethyl acetate); $\lambda_{max.}$ 344 mμ (in isooctane), $\epsilon_{max.}$ 19,500.

Found %: C 51.74, 51.8; H 4.91, 5.17. $C_{12}H_{14}O_4N_4$. Calculated %: C 51.8; H 5.0.

According to the data of Blaise, ethyl allyl ketone has the following constants: b.p. 126-127°, n_D^{15} 1.4212.

When the ethyl allyl ketone was distilled through a column packed with glass helices and having an efficiency of 18 theoretical plates it isomerized to ethyl propenyl ketone.

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* We were unable to isolate these ketones when we replaced the zinc in this reaction by magnesium and the benzene by ether; instead a viscous product with an amine odor was obtained.

Ethyl propenyl ketone, distilled through a column with an efficiency of 18 theoretical plates, had the following constants:

B.p. 136-137° at atmospheric pressure; n_D^{20} 1.4385, d_4^{20} 0.8537; MR_D 25.9, calcd. 24.83, $\lambda_{max.}$ 327 mμ (in isooctane). 2,4-dinitrophenylhydrazone was obtained as dark-red crystals with m.p. 141-142° (from ethyl acetate), $\lambda_{max.}$ 363 mμ (in isooctane); $\epsilon_{max.}$ 20000.

Found %: C 51.87, 51.80; H 5.11, 5.07. $C_{12}H_{14}O_4N_4$. Calculated %: C 51.8; H 5.0.

Yellow crystals with m.p. 168° (from a mixture of ethanol and ethyl acetate) were also isolated from the mother liquor, being the addition product of 2,4-dinitrophenylhydrazine to the 2,4-dinitrophenylhydrazone of ethyl propenyl ketone.

Found %: C 45.42, 45.33; H 4.17, 4.40. $C_{18}H_{20}O_8N_8$. Calculated %: C 45.4; H 4.2.

The semicarbazone of ethyl propenyl ketone melted at 155-156°.

Synthesis of ethynyl-Δ^1-cyclohexenylcarbinol (XI). To the Grignard reagent (obtained from 36 g of ethyl bromide and 7.8 g of magnesium in 300 ml of absolute ether) was added in 2 hours with constant stirring 35 g of cyclohexenylacetylene (b.p. 62° at 39 mm, n_D^{18} 1.4860 [43]) in 75 ml of absolute ether. The temperature rose from 16 to 22°. The reaction mixture was stirred until the evolution of ethane ceased (6 hours at 30-35°). To the solution, cooled to 7°, was added in 30 minutes 15 g of acetaldehyde, after which the stirring was continued for another 30 minutes at 5-8°. The next day the reaction mixture was stirred for 4 hours at 10-15°, and then it was treated with concentrated ammonium chloride solution. The ether layer was separated, the water layer was extracted with ether, and the combined ether solution was washed with water and then dried over sodium sulfate. After distilling off the ether the residue was vacuum-distilled. We obtained 30 g of carbinol (XI) with b.p. 105-106° at 5mm; n_D^{15} 1.5240 [36].

Isomerization of ethynyl-Δ^1-cyclohexenylcarbinol (XI). To the Nieuwland catalyst (obtained from 1 g of mercuric oxide, 1 ml of boron trifluoride etherate and 2 ml of isopropyl alcohol) was added 25 ml of dry isopropyl alcohol, and then with constant stirring 22.5 g of carbinol (XI) was introduced in 1 hour. Here the temperature rose from 14 to 19°. After stirring for 2 hours at 30-35° the reaction mixture was filtered, washed with sodium bicarbonate solution, and dried over sodium sulfate. After distilling off the solvent the residue was vacuum-distilled. We obtained 19 g of substance with b.p. 108-110° at 5 mm, n_D^{18} 1.5165. The polymeric residue weighed 3 g.

From 16 g of this substance we obtained 9 g of the 2,4-dinitrophenylhydrazone with m.p. 210-230° (it deposited in portions over a period of a month), from which after several recrystallizations we isolated the hydrazone of the cyclic ketone (VIII) with m.p. 240-241°. The mixed melting point with the authentic specimen was not depressed.

When the isomerization of carbinol (XI) was run in dry acetone in the presence of mercury sulfate we were able to identify in the reaction products through the 2,4-dinitrophenylhydrazone only the cyclic ketone (VIII). In not a single case were we able to show the presence of the hydrazones of propenyl-Δ^1-cyclohexenyl ketone (VI).

Hydration of vinylisopropenylacetylene (XIX). A mixture of 300 g of dienyne (XIX), b.p. 33-34° at 44 mm, n_D^{20} 1.4970 [44], 400 g of 80% methanol and 10 g of mercury sulfate was stirred for 2 hours at 60-62° (thermometer in the liquid). Then in two portions at 2 hour intervals another 10 g of catalyst was added, and stirring at 60-65° was continued for another 2 hours (the total time of stirring at 60-65° was 8 hours). The solution was filtered, the methanol vacuum-distilled at 60-70 mm (at a bath temperature not exceeding 30-35°), the residue diluted with water, neutralized with soda, and extracted with ether. After drying over sodium sulfate the ether was distilled off, while the residue was vacuum-distilled from a Favorsky flask. We obtained 253 g of a mixture of substances with b.p. 40-80° (14 mm) and 60 g of polymeric residue. Two fractional distillations of this mixture gave the following fractions (at 20 mm): 1st b.p. 55-60°, n_D^{20} 1.4670, 40 g, 2nd, b.p. 61-65°, n_D^{20} 1.4580, 40 g; 3rd, b.p. 66-74°, n_D^{20} 1.4470, 65 g; 4th, b.p. 75-79°, n_D^{20} 1.4450, 35 g; 5th, b.p. 80-85°, n_D^{20} 1.4495, 25 g; 6th, b.p. 86-94°, n_D^{20} 1.4440, 27 g.

The first fraction was distilled through a column with an efficiency of 25 theoretical plates; here we isolated the pure propenyl isopropenyl ketone (XXI) as a mobile liquid with yellow color:

B.p. 55° (16 mm, n_D^{20} 1.4735, d_4^{20} 0.8871, MR_D 34.8; calcd. 33.6, $\lambda_{max.}$ 240, 340 mμ (in methanol).

The 2,4-dinitrophenylhydrazone of dienone (XXI) was obtained as dark-orange crystals with m.p. 157-158° (from a mixture of ethanol and ethyl acetate), $\lambda_{max.}$ 361 mμ (in isooctane), $\epsilon_{max.}$ 21000.

Found %: C 53.59, 53.81; H 4.70, 4.79; N 19.11, 18.93. $C_{13}H_{14}O_4N_4$. Calculated %: C 53.78; H 4.72; N 19.3.

A small amount of a 2,4-dinitrophenylhydrazone was isolated from the mother liquor as bright-yellow crystals; after recrystallization from a mixture of ethanol and benzene, m.p. 239-240° (with decompn.).

Found %: N 22.89. $C_{19}H_{20}O_8N_8$. Calculated %: N 22.92.

As can be seen from the analysis data, this substance corresponds to the addition product of 2,4-dinitrophenylhydrazine to the above described hydrazone of propenyl isopropenyl ketone with m.p. 157-158°.

From the head fraction (b.p. 46-54° at 16 mm, n_D^{20} 1.4690), isolated after distillation of the first fraction through a column, we also obtained the 2,4-dinitrophenylhydrazones with m.p. 157-158° and 234-235°. The mixed melting point of these hydrazones with the above described specimens was not depressed.

Distillation of the fourth fraction (35 g) through the above indicated column gave β-methoxypropyl isopropenyl ketone (XXII) as a colorless mobile liquid, which on storage polymerized to a hard polymer:

B.p. 66.0-67.0° (13 mm); n_D^{20} 1.4410, d_4^{20} 0.9258, MR_D 40.58; calcd. 40.33; $\lambda_{max.}$ 324 mμ (in isooctane); $\lambda_{max.}$ 315 mμ (in methanol); the 2,4-dinitrophenylhydrazone was obtained as yellow needles with m.p. 107-108° (from a mixture of ethanol and ethyl acetate); $\lambda_{max.}$ 372 mμ (in isooctane).

Found %: C 52.24, 52.15; H 5.70, 5.83; N 17.81, 17.71. $C_{14}H_{18}O_5N_4$. Calculated %: C 52.16; H 5.6; N 17.42.

From the sixth fraction (27 g) after distillation through the column we isolated 10 g of β-methoxyisopropyl propenyl ketone (XXIII) and 4 g of β-methoxypropyl β-methoxyisopropyl ketone (XXIV).

The first ketone is a nearly colorless liquid that does not polymerize:

B.p. 89-90° (16 mm), n_D^{20} 1.4455, d_4^{20} 0.9374, MR_D 41.2; calcd. 40.33; $\lambda_{max.}$ 250, 322 mμ (in isooctane); $\lambda_{max.}$ 237; 312 mμ (in methanol); the crystalline 2,4-dinitrophenylhydrazone deposits in small amount as dark-red crystals (mainly an oily mass is obtained) with m.p. 104-105° (from a mixture of ethanol and ethyl acetate); $\lambda_{max.}$ 371 mμ (in heptane).

Found %: C 52.22; H 5.73. $C_{14}H_{18}O_5N_4$. Calculated %: C 52.16; H 5.6.

The dimethoxy ketone (XXIV) was obtained as a colorless mobile liquid:

B.p. 99-100° (18 mm), n_D^{20} 1.4260, d_4^{20} 0.9468, MR_D 47.10; calcd. 47.05; $\lambda_{max.}$ 228, 275 mμ (in isooctane), $\lambda_{max.}$ 235 mμ (in methanol); the compound does not give a crystalline 2,4-dinitrophenylhydrazone.

Cleavage of methanol from methoxy ketones (XXII), (XXIII) and (XXIV). A mixture of 58 g of the methoxy ketones (b.p. 70-75° at 18 mm, n_D^{20} 1.4470) was heated in the presence of 0.1 g of p-toluenesulfonic acid at 100° and a vacuum of 85-100 mm for 2 hours. After removal of the methanol the residue was vacuum-distilled.. We obtained 22 g of substance, the distillation of which through a column with an efficiency of 25 theoretical plates gave 18 g of propenyl isopropenyl ketone (XXI) with b.p. 47° at 11 mm, n_D^{20} 1.4730, d_4^{20} 0.8851.

The 2,4-dinitrophenylhydrazone with m.p. 157-158° was obtained in predominant amount from this dienone. The mixed melting point with the above described specimen was not depressed. The mother liquor yielded a small amount of a 2,4-dinitrophenylhydrazone as orange crystals with m.p. 123-124° (from a mixture of ethanol and ethyl acetate); $\lambda_{max.}$ 362 mμ (in isooctane): $\epsilon_{max.}$ 21000.

Found %: C 53.91, 53.80; H 4.90, 4.89; N 19.57, 19.67. $C_{13}H_{14}O_4N_4$. Calculated %: C 53.78; H 4.72; N 19.3.

This 2,4-dinitrophenylhydrazone is extremely unstable and when repeatedly recrystallized from a mixture of ethanol and ethyl acetate it partially polymerized to the 2,4-dinitrophenylhydrazone with m.p. 157-158°. After storage for a year a specimen of the hydrazone with m.p. 124-125° melted at 121-130°.

Isomerization of 2-methyl-1-hexen-3-yn-5-ol (XXV). Carbinol (XXV) (b.p. 72° at 14 mm, 78° at 21 mm, n_D^{20} 1.4810) was obtained in 69% yield by the reaction of acetaldehyde with isopropenylacetylenemagnesium bromide [35].

A mixture of 55 g of carbinol (XXV), 100 g of dry acetone and 5.5 g of mercury sulfate (added in portions) was stirred for 6 hours at 60-62° (the catalyst was not reduced); after filtration the acetone was removed by distillation under slight vacuum, while the residue was distilled from a Favorsky flask. We obtained 36 g of a mixture of substances with b.p. 62-75° (18 mm) and 13 g of a polymeric residue. After two distillations from a Favorsky flask, and then through a column with an efficiency of 18 theoretical plates, we isolated from this mixture 10 g of the starting carbinol (XXV) (b.p. 66-70° at 12 mm, n_D^{21} 1.4770), 6 g of propenyl isopropenyl ketone (XXI) (b.p. 49-50° at 12 mm, n_D^{20} 1.4720, d_4^{20} 0.8890; the 2,4-dinitrophenylhydrazone melted at 157-158°) and 8 g of 1,3-dimethyl-Δ^1-cyclopenten-5-one (b.p. 55-56° at 12 mm, n_D^{20} 1.4680; the 2,4-dinitrophenylhydrazone melted at 209-210°).

The melting point of all of the 2,4-dinitrophenylhydrazones was not depressed when mixed with authentic specimens.

The isomerization of carbinol (XXV) (39 g) in anhydrous methanol solution with the Nieuwland catalyst gave 38 g of a mixture of methoxy ketones (XXII), (XXIII) and (XXIV) and 1,3-dimethyl-Δ^1-cyclopenten-5-one. Distillation of this mixture in the presence of p-toluenesulfonic acid and then through the column gave a mixture of propenyl isopropenyl ketone (XXI) (the 2,4-dinitrophenylhydrazone melted at 157-158°) and 1,3-dimethyl-Δ^1-cyclopenten-5-one (the 2,4-dinitrophenylhydrazone melted at 206-207°). The mixed melting point of these 2,4-dinitrophenylhydrazones with the above described specimens was not depressed.

The isomerization of carbinol (XXV) with Nieuwland catalyst in dry isopropyl alcohol solution (2.5 hours, 40-45°) and in absolute ether (7 hours, 35-37°) gave mainly the unreacted carbinol. The first fraction was shown to contain propenyl isopropenyl ketone (XXI) and 1,3-dimethyl-Δ^1-cyclopenten-5-one, identified through their 2,4-dinitrophenylhydrazones.

Attempted cyclization of propenyl isopropenyl ketone (XXI) under the influence of mercury sulfate. A mixture of 15 g of dienone (XXI) (b.p. 65-66° at 30 mm, n_D^{20} 1.4730), 30 g of dry acetone and 1.5 g of mercury sulfate (added in portions) was stirred for 5 hours at 60-63°. After filtration and removal of the acetone by distillation the residue was vacuum-distilled. We obtained 10 g of the original dienone with b.p. 57-59° (20 mm), n_D^{20} 1.4725 and 3.5 g of polymeric residue.

The 2,4-dinitrophenylhydrazone of this dienone melted at 157-158° and its mixed melting point with the authentic specimen was not depressed.

Preparation of the low-boiling cis-isomer of propenyl isopropenyl ketone (XXI). Two kilograms of the mixed methoxy ketones (XXII), (XXIII) and (XXIV) was heated in the presence of 3.5 g of p-toluenesulfonic acid, as described above, in a vacuum of 90-100 mm at a bath temperature of 100-110°. After distilling off the methanol the obtained dienone was distilled through a column with an efficiency of 25 theoretical plates and here we obtained 850 g of dienone (XXI) with b.p. 53° at 17 mm, n_D^{20} 1.4730, and in addition, we isolated 40 g of a head fraction with b.p. 49-52° at 17 mm, n_D^{20} 1.4685. Repeated fractional distillation of this head fraction from a Favorsky flask gave 8 g of the low-boiling cis-isomer of propenyl isopropenyl ketone (XXI) as a mobile, yellowish, lachrymatory liquid:

B.p. 45-47° (19 mm); 38-40° (10 mm); n_D^{20} 1.4660, d_4^{20} 0.8875, MR_D 34.37; calcd. 33.6; $\lambda_{max.}$ 241, 343 mμ (in methanol); $\lambda_{max.}$ 241, 341 mμ (in isooctane).

Found %: C 75.97; H 9.49. $C_7H_{10}O$. Calculated %: C 76.32; H 9.09.

When kept for 13 days the obtained low-boiling dienone (XXI) polymerized to a hard glassy polymer.

From this dienone under heating we obtained a 2,4-dinitrophenylhydrazone with m.p. 156-156°, the melting point of which was not depressed when mixed with the 2,4-dinitrophenylhydrazone of the high-boiling dienone (XXI). Preparation of the 2,4-dinitrophenylhydrazone under ice-cooling leads to the formation of a difficultly separable mixture with m.p. 98-125°, from which we were able to isolate in small amount only the above described 2,4-dinitrophenylhydrazone with m.p. 154-155°.

Hydrogenation of the low-boiling cis-isomer of dienone (XXI). Hydrogen was passed through a solution of 1.1 g of the dienone in 5 ml of absolute ether in the presence of platinum catalyst. The amount of hydrogen absorbed was 480 ml (theory is 485 ml). Distillation gave 0.9 g of propyl isopropyl ketone with b.p. 135-137°, n_D^{20} 1.4080, the semicarbazone of which melted at 120-121° and did not give a melting point depression with the authentic specimen.

Cyclization of the low-boiling cis-isomer of dienone (XXI). A mixture of 2.2 g of the dienone and 2 g of phosphoric acid (d 1.75) was heated for 2 hours at 60°. After the usual treatment and vacuum-distillation we obtained 1.1 g of 1,3-dimethyl-Δ^1-cyclopenten-5-one with b.p. 63° (17 mm), n_D^{20} 1.4670, the semicarbazone of which melted at 172-173° and did not give a melting point depression with the authentic specimen [40].

Isomerization of the low-boiling cis-isomer of dienone (XXI). Two grams of the low-boiling dienone (XXI) (b.p. 47-49° at 20 mm, n_D^{20} 1.4660) was heated with an iodine crystal in the presence of pyrogallol for 1 hour at 100°. After two distillations we obtained 1 g of the high-boiling trans-isomer of dienone (XXI) with b.p. 57-58° (20 mm), n_D^{20} 1.4705. The 2,4-dinitrophenylhydrazone melted at 155-156° and did not give a melting point depression with the authentic specimen.

Hydration of 5-methyl-1,5-heptadien-3-yne (XXVI). Dienyne (XXVI) (b.p. 42-43° at 24 mm, n_D^{20} 1.5040) was obtained by the dehydration of methylethylvinylethynylcarbinol, as described earlier [44].

A mixture of 128 g of dienyne (XXVI), 260 g of 80% methanol and 5 g of mercury sulfate was stirred at 65-67° for 45 minutes (temperature inside the liquid 67-69°), the methanol was vacuum-distilled at a bath temperature not exceeding 30°, the residue was neutralized with soda (7 g), extracted with ether, and dried over sodium sulfate. After distilling off the ether the residue was vacuum-distilled. 16 g original dienyne and 70 g of substance with b.p. 60-90° (17 mm), the fractional distillation of which from a Favorsky flask gave (at 17 mm): 1st, 70-78°, n_D^{20} 1.4750, 38 g; 2nd, b.p. 79-86°, n_D^{20} 1.4810, 19 g; 3rd, b.p. 87-89°, n_D^{20} 1.4760, 4 g.

Redistillation of the first fraction through a column with an efficiency of 18 theoretical plates gave 25 g of the low-boiling cis-isomer of dienone (XXVIII) as a slightly yellowish mobile liquid:

B.p. 76.5-77.5°, 21 mm, 67-69° (17 mm), n_D^{20} 1.4720, d_4^{20} 0.886, MR_D 39.26; calcd. 38.22; $\lambda_{max.}$ 235, 322 mμ (in methanol), $\epsilon_{max.}$ 22400.

The 2,4-dinitrophenylhydrazone, obtained by the above described method with ice-cooling, melted at 158-159° (from a mixture of ethanol and ethyl acetate); the UV absorption spectrum of this 2,4-dinitrophenylhydrazone had $\lambda_{max.}$ 371 mμ (in isooctane); $\epsilon_{max.}$ 20,000, characteristic for the ketones with two conjugated double bonds.

Found %: C 55.01; H 5.43; N 18.72. $C_{14}H_{16}O_4N_4$. Calculated %: C 55.25; H 5.3; N 18.41.

A small amount of bright-yellow crystals with m.p. 250° was also isolated from the mother liquor, apparently being the addition product of 2,4-dinitrophenylhydrazine to the 2,4-dinitrophenylhydrazone of dienone (XXVIII), and also the 2,4-dinitrophenylhydrazone of 2-ethoxy-5-methyl-5-hepten-4-one with m.p. 117-118° (from a mixture of ethanol and ethyl acetate); $\lambda_{max.}$ 371 mμ (in isooctane).

Found %: C 54.12; H 6.28. $C_{16}H_{22}O_5N_4$. Calculated %: C 54.26; H 6.33.

The distillation of the second and third fractions through the above indicated column gave 10 g of the high-boiling trans-isomer of dienone (XXVIII) as a pale yellow mobile liquid:

B. p. 90-91° and 22 mm, n_D^{20} 1.4870, d_4^{20} 0.9034, MR_D 39.26; calcd. 38.22; $\lambda_{max.}$ 245, 324 mμ (in methanol): $\epsilon_{max.}$ 24500.

This dienone gave the 2,4-dinitrophenylhydrazone as a mixture of dark-red and orange crystals with the same m.p. 158-159° (from a mixture of ethanol and ethyl acetate). When heated to 140° the orange crystals are converted to the red modification. The mixed melting point of the red and orange modifications is not depressed; that of the 2,4-dinitrophenylhydrazone, isolated from the low-boiling cis-isomer of (XXVIII), was also not depressed.

From the mother liquor we isolated the above described hydrazone with m.p. 250°.

The hydration of dienyne (XXVI) in the presence of mercury sulfate and sulfuric acid leads predominantly to the formation of the high-boiling trans-isomer [29] of dienone (XXVIII). The prolonged (13 hours) hydration of dienyne (XXVI) in the presence of sulfuric acid and mercury sulfate gives, together with dienone (XXVIII) and 2-methoxy-5-methyl-5-hepten-4-one, a small amount of 2-methyl-2-ethyltetrahydro-4-pyrone (in the head fraction), identified through its semicarbazone with m.p. 193-194° (from ethanol).

Found %: N 21.03, 21.19. $C_9H_{17}O_2N_3$. Calculated %: N 21.11.

Isomerization of the low-boiling cis-isomer of dienone (XXVIII). Five grams of the low-boiling dienone (XXVIII) (b.p. 67-69° at 17 mm, n_D^{20} 1.4720) was heated in the presence of pyrogallol with an iodine crystal at 100° for 2 hours. After two distillations we isolated 3 g of the high-boiling trans-isomer of dienone (XXVIII) with b.p. 81-82° (16.5 mm), n_D^{20} 1.4890, d_4^{20} 0.9034.

The low-boiling cis-isomer of dienone (XXVIII) is also isomerized to the high-boiling trans-isomer by heating in the presence of pyrogallol for 3 hours at 170-180°.

When dienone (XXVIII) was kept for a year in a nitrogen atmosphere in the presence of pyrogallol it underwent partial oxidation with the formation of acid products.

SUMMARY

The hydration of divinylacetylene hydrocarbons (I) in aqueous methanol solutions in the presence of mercury sulfate yields vinyl propenyl ketones (III) with conjugated double bonds. In this connection we were unable to isolate the vinyl allyl ketones (II), which appear as the primary hydration products.

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REACTION OF 3-METHYL-3-ETHYL-1-PENTYNE WITH THE LOWER SATURATED MONOBASIC ACIDS

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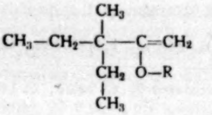
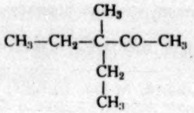
We had described the addition of acetic, propionic and butyric acids to 1-octyne, leading to the formation of the corresponding monosubstituted vinyl β-esters and methyl hexyl ketone [1].

In the present paper we studied the reaction of the same acids with the isomer of 1-octyne, with 3-methyl-3-ethyl-1-pentyne, in the presence of their mercury salts and boron fluoride etherate. Here we isolated: 2-acetoxy-3-methyl-3-ethyl-1-pentene (I), 2-propionyloxy-3-methyl-3-ethyl-1-pentene (II), 2-butyroxy-3-methyl-3-ethyl-1-pentene (III), and in all cases 3-methyl-3-ethyl-2-pentanone (IV).



$CH_3{-}CH_2{-}\overset{CH_3}{\underset{CH_2CH_3}{C}}{-}\underset{O-R}{C}{=}CH_2$



$CH_3{-}CH_2{-}\overset{CH_3}{\underset{CH_2CH_3}{C}}{-}CO{-}CH_3$

(IV)

(I) $R = COCH_3$, (II) $R = COC_2H_5$, (III) $R = COC_3H_7$

The properties of the last product (IV) coincide with the properties of the same ketone, obtained by the dehydration of 3,4-dimethyl-3,4-hexanediol with concentrated sulfuric acid [2]. We attempted to obtain 3-methyl-3-ethyl-2-pentanone from 3-methyl-3-ethyl-2-pentanol by the oxidation of the latter with chromic mixture, but as a result of this reaction we obtained other substances that were not investigated.

All of the esters described by us are colorless, clear, mobile liquids, having an odor reminiscent of the odor of ketone (IV). The position of the acyloxy groups in the molecules of esters (I), (II) and (III) was determined by the method of their hydrolysis in the presence of semicarbazide acetate. This method had been developed by us and was first used on the specimens described earlier [1].

The formation in good yields of only the 3-methyl-3-ethyl-2-pentanone semicarbazone in all three cases supports the validity of formulas (I), (II) and (III).

EXPERIMENTAL

3-Methyl-3-ethyl-1-pentyne was first synthesized by Davis and Marvel [3] from the pinacolin obtained by the dehydration of 3,4-dimethyl-3,4-hexanediol. We obtained this acetylenic hydrocarbon as the result of cleaving the elements of hydrogen chloride from 1,1-dichloro-3-methyl-3-ethylpentane, and the latter by the method of L. Schmerling [4], by the condensation of vinyl chloride with methyldiethylchloromethane in the presence of anhydrous aluminum chloride.

1,1-Dichloro-3-methyl-3-ethylpentane. Dry Ice was used to effect the liquefaction of 45 liters of vinyl chloride. To the liquid vinyl chloride was added 95.5 g of methyldiethylchloromethane (b.p. 24-25° at 11 mm) and then 15 g of anhydrous aluminum chloride was added in 5.0 g portions over a period of 3.5 hours. The reaction mixture was kept in a Dry Ice bath and stirred continuously. Reaction began 5.5 hours after adding the first portion of aluminum chloride and lasted for 5 minutes, after which the cooled reaction products were stirred at room temperature for 45 minutes, then treated with concentrated hydrochloric acid to complete solution of the basic aluminum salts, and extracted with ether. The ether extract was washed with soda solution and dried over fused calcium chloride. As the result of removing the solvent and 2 vacuum-distillations we isolated 68.5 g (47.3%) of 1,1-dichloro-3-methyl-3-ethylpentane.

B.p. 75.5-76° (7 mm), d_0^0 1.0460 d_{20}^{20} 1.0292, d_4^{20} 1.0040, n_D^{20} 1.4570, MR_D 49.68; calculated 49.62
Found %: Cl 38.70, 38.70. $C_8H_{16}Cl_2$. Calculated %: Cl 38.73.

3-Methyl-3-ethyl-1-pentyne. To 110 g of molten potassium hydroxide with continuous stirring was added in drops 56.8 g of 1,1-dichloro-3-methyl-3-ethylpentane (b.p. 75.5-76° at 7 mm). Here the reaction products were distilled off and again passed through the same alkali. The distillate was dried over calcium chloride and distilled twice at ordinary pressure. We isolated 21.2 g (62.5%) of 3-methyl-3-ethyl-1-pentyne.

B.p. 101.5-102.5°, d_0^0 0.7595, d_{20}^{20} 0.7432, d_4^{20} 0.7422, n_D^{20} 1.4110, MR_D 36.87. $C_8H_{14}F$. Calculated 37.14.

Found %: C 87.04; H 12.99. C_8H_{14}. Calculated %: C 87.20; H 12.80.

From the literature [3]: 3-methyl-3-ethyl-1-pentyne boils at 98-100° (745 mm).

1-Chloro-3-methyl-3-ethyl-1-pentene. The intermediate fractions, accumulating in the process of synthesizing 3-methyl-3-ethyl-1-pentyne, were combined and again subjected to vacuum distillation, as a result of which 1-chloro-3-methyl-3-ethyl-1-pentene was isolated.

B.p. 40-41° (8 mm), d_0^0 0.9399, d_{20}^{20} 0.9255, d_4^{20} 0.9240, n_D^{20} 1.4485, MR_D 42.53. $C_8H_{15}ClF$. Calculated: 43.54.

Found %: Cl 24.11, 24.14. M 130. $C_8H_{15}Cl$. Calculated %: Cl 24.18. M 147.

2-Acetoxy-3-methyl-3-ethyl-1-pentene. A mixture of 14.7 g of acetic acid, 2.5 g of acetic anhydride and 1.7 g of mercuric oxide was heated until the oxide had dissolved completely. To the cooled solution was added 22 g of 3-methyl-3-ethyl-1-pentyne (b.p. 101.5-102.5°) and 1.0 ml of boron fluoride etherate $BF_3 \cdot O(C_2H_5)_2$ (b.p. 124-126.5°). The reaction mixture was heated on the boiling water bath for 1 hour without any visible signs of reaction, for which reason an additional 1.0 ml of $BF_3 \cdot O(C_2H_5)_2$ was added. The stirring and heating on the water bath was continued for another 3 hours, after which the reaction mixture was cooled and extracted with ether, and the ether extract was washed with soda solution and dried over calcium chloride. As the result of removing the solvent and four vacuum-distillations we obtained 12.1 g (36.2%) of 2-acetoxy-3-methyl-3-ethyl-1-pentene.

B.p. 55-56° (23 mm), d_0^0 0.8513, d_{20}^{20} 0.8377, d_4^{20} 0.8365, n_D^{20} 1.4200, MR_D 51.50. $C_{10}H_{18}O_2F$. Calculated: 49.58.

Found %: C 70.44, 70.55; H 10.75, 10.73. M 171. $C_{10}H_{18}O_2$. Calculated %: C 70.55; H 10.66. M 170.

As by-products we isolated 1.0 g of high-molecular substances, which were not investigated, and established the presence of 4.5 g of 3-methyl-3-ethyl-2-pentanone by its semicarbazone. About 1.5 g of the starting hydrocarbon was shown in the first fraction by the formation of the silver acetylenide.

The semicarbazones, isolated from the initial fractions of the reaction products, after recrystallization from alcohol melted at 167-169°, which agrees completely with the literature data [2] for the semicarbazone of 3-methyl-3-ethyl-2-pentanone, and failed to depress the melting point when mixed with the semicarbazone of 3-methyl-3-ethyl-2-pentanone, obtained as the result of hydrolyzing the ester in the presence of semicarbazide acetate.

2-Acetoxy-3-methyl-3-ethyl-1-pentene with semicarbazide acetate. 1.00-1.05 g of 2-acetoxy-3-methyl-3-ethyl-1-pentene (b.p. 55-56° at 23 mm) was mixed with 22-23 ml of semicarbazide acetate solution, prepared as described in the previous paper [1], and then kept at 48° for 18 hours.

The isolated semicarbazone melted at 166.5-168° and failed to depress the melting point when mixed with an equal amount of the semicarbazones, isolated from the intermediate fractions of the reaction products of 3-methyl-3-ethyl-1-pentyne with acetic, propionic and butyric acids. The yield was nearly quantitative. Only 3-methyl-3-ethyl-2-pentanone is formed as the result of hydrolyzing 2-acetoxy-3-methyl-3-ethyl-1-pentene. The semicarbazone of the aldehyde isomeric to it was not revealed.

2-Propionyloxy-3-methyl-3-ethyl-1-pentene. Forty grams of 3-methyl-3-ethyl-1-pentyne was treated with 27.4 g of propionic acid, containing in the dissolved state 2.2 g of mercuric oxide and 2.0 ml of boron fluoride etherate, in exactly the same manner as described in the previous case. Here 7.2 g (10.8%) of 2-propionyloxy-3-methyl-3-ethyl-1-pentene was isolated.

B.p. 87-88° (84 mm), d_0^0 0.8710, d_{20}^{20} 0.8552, d_4^{20} 0.8539, n_D^{20} 1.4170, MR_D 54.27. $C_{11}H_{20}O_2F$. Calculated: 54.19.

Found %: C 71.72, 71.70; H 11.02, 11.00. M 145. $C_{11}H_{20}O_2$. Calculated %: C 71.69; H 10.94. M 184.

A study of the remaining fractions of the reaction products revealed that 8 g of the starting hydrocarbon proved to be bound as high-molecular products, not subjected to further study, 8.5 g failed to react, and 5.5 g was consumed to form 3-methyl-3-ethyl-2-pentanone, the presence of which was established by isolating the semicarbazone with m.p. 167-168°.

The heating (15 hours, 48°) of 0.5 g of 2-propionyloxy-3-methyl-3-ethyl-1-pentene with excess semicarbazide acetate solution [1] gave a semicarbazone with m.p. 167-168°, proving to be the semicarbazone of 3-methyl-3-ethyl-2-pentanone (mixed melting point) [2].

2-Butyroxy-3-methyl-3-ethyl-1-pentene. 55.2 g of 3-methyl-3-ethyl-1-pentyne (b.p. 101.5-102.5°) was treated with 44.0 g of butyric acid (b.p. 161-163°), in which 1.7 g of mercuric oxide and 2.0 ml of boron fluoride etherate had been previously dissolved, under roughly the same conditions as in the previous cases. Here we isolated 3.6 g (3.7%) of 2-butyroxy-3-methyl-3-ethyl-1-pentene.

B.p. 53.5-54.5° (21 mm), d_0^0 0.8557, d_{20}^{20} 0.8410, d_4^{20} 0.8398, n_D^{20} 1.4210, MR_D 59.47. $C_{12}H_{22}O_2F$. Calculated 58.80.

Found %: C 72.82, 72.69; H 11.25, 11.26. M 119. $C_{12}H_{22}O_2$. Calculated %: C 72.68; H 11.16. M 198.

A study of the remaining fractions of the reaction products revealed that approximately 11.6 g of the starting hydrocarbon went for the formation of high-molecular substances, 12 g went for the formation of 3-methyl-3-ethyl-2-pentanone, the presence of which was established by the semicarbazone with m.p. 167-168°, and that 25 g of unreacted acetylenic hydrocarbon was present, apparently driven out during the four vacuum-distillations. The reaction of 2-butyroxy-3-methyl-3-ethyl-1-pentene with semicarbazide acetate was run in exactly the same manner as in the previous case. The semicarbazone of 3-methyl-3-ethyl-2-pentanone with m.p. 166.5-168° (from alcohol) was isolated. The yield was nearly quantitative. The semicarbazone of the aldehyde, isomeric with this ketone, was not found among the hydrolysis products of the ester.

3-Methyl-3-ethyl-2-pentanol. To 12 g of magnesium turnings, covered with absolute ether, was added a solution of 83 g of methyldiethylbromomethane (b.p. 30.5° at 9 mm) in an equal volume of ether. The reaction rate was regulated so that the difference between the levels in the Tishchenko closure flask was insignificant. In 2-3 hours after adding all of the bromide the addition of 22 g of acetaldehyde, diluted with absolute ether in a 1:1 ratio, was made to the reaction mixture in the regular manner. The next day the reaction mixture was decomposed with water, acidified with hydrochloric acid, and treated with ether. The ether extract was washed with soda and dried over fused sodium sulfate. Removal of the ether and four vacuum-distillations gave 3.2 g (4.9%) of 3-methyl-3-ethyl-2-pentanol.

B.p. 55-57° (5 mm), d_0^0 0.8712, d_{20}^{20} 0.8589, d_4^{20} 0.8576, n_D^{20} 1.4488, MR_D 40.71; calc. 40.67.
Found %: C 73.74, 73.61; H 14.02, 14.03. $C_8H_{18}O$. Calculated %: C 73.78; H 13.93.

An attempt to oxidize this alcohol to the corresponding ketone proved unsuccessful.

3-Methyl-3-ethyl-2-pentanone. As the result of treating the combined intermediate fraction of the reaction products obtained from the reaction of 3-methyl-3-ethyl-1-pentyne with acetic, propionic and butyric acids with excess semicarbazide acetate we isolated 9 g of the semicarbazone of 3-methyl-3-ethyl-2-pentanone with m.p. 167-168° To it we added 150 ml of 13% sulfuric acid, after which the reaction mixture was boiled, and the hydrolysis products were steam-distilled; to retain a constant sulfuric acid concentration the loss of water from the reaction flask was compensated for by adding water from a dropping funnel. The presence of two layers in the distillate was observed: the upper layer being the ketone, and the bottom layer being water. The ketone was separated, washed with soda solution, dried over calcium chloride, and distilled at ordinary pressure. The yield was 4.5 g (90%).

B.p. 153-154°, d_0^0 0.8514, d_{20}^{20} 0.8366, d_4^{20} 0.8354, n_D^{20} 1.4210, MR_D 38.92; calc. 39.16.
Found %: C 74.93; H 12.57, 12.56. $C_8H_{16}O$. Calculated %: C 74.94; H 12.57.

From the literature [2]: ketone (IV) boils 153.5-154° and has d_4^{20} 0.8389.

From the 3-methyl-3-ethyl-2-pentanone we obtained the semicarbazone with m.p. 166.5-167.5° [2] (from alcohol).

Found %: N 22.79. $C_9H_{19}ON_3$. Calculated %: N 22.68.

SUMMARY

1. Three new vinyl esters were synthesized and described: 2-acetoxy-3-methyl-3-ethyl-1-pentene, 2-propionyloxy-3-methyl-3-ethyl-1-pentene and 2-butyroxy-3-methyl-3-ethyl-1-pentene.

2. Included in the intermediate products of the synthesis of 3-methyl-3-ethyl-1-pentyne, and in the products associated with the synthesis of 3-methyl-3-ethyl-2-pentanone, the compounds 1,1-dichloro-3-methyl-3-ethylpentane, 1-chloro-3-methyl-3-ethyl-1-pentene and 3-methyl-3-ethyl-2-pentanol were obtained and described for the first time.

3. To determine the position of the acyloxy groups in the ester molecules we used the method of their hydrolysis in the presence of semicarbazide acetate.

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TRANSFORMATIONS OF SYM. PHENYLCYCLOHEXYLETHYLENE OXIDE AND OF ITS CORRESPONDING SYM. PHENYLCYCLOHEXYLETHYLENE GLYCOL

A. I. Bolshukhin and A. N. Orlova

Earlier one of us, together with E. D. Venus-Danilova [1], had shown that phenylcyclohexylacetaldehyde (I), by the Danilov and Venus-Danilova reaction, when reacted with strong sulfuric acid in the cold and with mercuric sulfate in alcohol-water medium under heating, is converted only into benzyl cyclohexyl ketone (II). The second possible ketone-phenyl hexahydrobenzyl ketone (III) – could not be shown by us to be present among the reaction products.

In this connection a study of the interrelationships between the three mentioned substances (I, II, III) and sym. phenylcyclohexylethylene oxide (IV) deserves first consideration, and secondly, the interrelationships between them and sym. phenylcyclohexylethylene glycol (V).

We obtained sym. phenylcyclohexylethylene oxide (IV) by the N. A. Prilezhaev method [2], by the oxidation of sym. phenylcyclohexylethylene with benzoyl hydroperoxide, while the sym. phenylcyclohexylethylene glycol (V) was obtained by us by the hydration of oxide (IV) at room temperature in dilute hydrochloric acid (1:10).

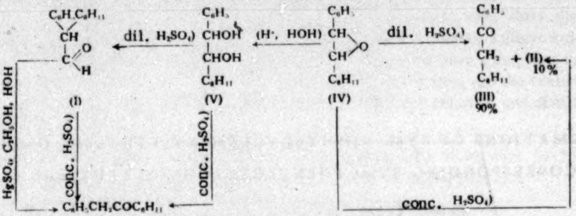
The literature on the isomerization of aldehydes, ketones and α-oxides, and also on the dehydration of α-glycols, is very extensive [3]. It was shown by S. N. Danilov that cyclohexylhydrobenzoin [4] in concentrated sulfuric acid in the cold is converted only into benzhydryl cyclohexyl ketone. Diphenylcyclohexylacetaldehyde also isomerizes to the same ketone under similar conditions. The heating of cyclohexylhydrobenzoin with crystalline oxalic acid or with 50% sulfuric acid gives diphenylcyclohexylacetaldehyde and both of the ketones isomeric with it–cyclohexyldesoxybenzoin and benzhydryl cyclohexyl ketone; when either the time of heating or the sulfuric acid concentration is increased the amount of aldehyde in the dehydration products of the glycol is reduced due to an increase in the amount of primarily the benzhydryl cyclohexyl ketone.

Methylphenylacetaldehyde, unsym. methylphenylethylene oxide and unsym. methylphenylethylene glycol [5] in concentrated sulfuric acid, in the cold, migrate into methyl benzyl ketone. The assertion of F. Ya. Perveev [6] that disubstituted α-oxides of unsymmetrical structure give exclusively aldehydes and that the isomerization of unsym. methylphenylethylene oxide (α-methylstyrene) leads only to methylphenylacetaldehyde is in distinct contradiction to the facts. In moderately acid medium the unsym. methylphenylethylene oxide is converted to the aldehyde (up to 64%), at room temperature in dilute hydrochloric acid (1:10) it is hydrated to the unsym. methylphenylethylene glycol, and the latter in moderately concentrated acid is converted either to only methylphenylacetaldehyde or to a mixture of the aldehyde and methyl benzyl ketone.

Depending on the experimental conditions the unsym. dicyclohexylethylene also gives either dicyclohexylacetaldehyde or the ketone 1,2-dicyclohexylethanone [7].

In this paper it is shown by us that in the reaction with concentrated sulfuric acid in the cold, studied by us earlier for phenylcyclohexylacetaldehyde (I) [1], sym. phenylcyclohexylethylene oxide (IV) and sym. phenylcyclohexylethylene glycol (V) are transformed into benzyl cyclohexyl ketone (II).

When heated with dilute sulfuric acid glycol (V) is transformed into phenylcyclohexylacetaldehyde (I) (67% yield), while oxide (IV) is transformed into both isomeric ketones (III) and (II), the amounts of which are found to be in the ratio 9:1.



When the results of transforming aldehydes, α-oxides and α-glycols, both from literature data [4,5] and those realized by us, are compared with conditions under which these transformations occurred it is impossible not to detect a number of rules. From the corresponding aldehyde, α-oxide and α-glycol in concentrated sulfuric acid in the cold the same ketone, being the most stable under comparable drastic formation conditions, is always formed. A. E. Favorsky [8], who considered the dehydration of pinacols as an oxidation-reduction process and termed it isomeric transformation, mentioned that the direction of this transformation depends on the greater oxidation tendency shown by one of the two neighboring hydroxylated carbon atoms of the α-glycol. He considered this tendency the basic reason for the corresponding direction of the dehydration of α-glycols, and the shifting of the radicals as the consequence of this reason. For example, the phenyl group reduces the reduction capacity of the hydroxylated carbon to which it is connected, while aliphatic radicals, and especially the methyl group, enhance this capacity, and consequently from the α-glycols, in particular from pinacols, ketones with the acetyl group are obtained as the result of dehydration.

Instead of the methyl group, the cyclohexyl radical is found in the sym. phenylcyclohexylethylene glycol (V) and in the cyclohexylhydrobenzoin [4] studied by us.

Depending on the reaction conditions and the properties of the reacting and formed molecules, the dehydration of α-glycols with moderately concentrated acid leads either to only aldehydes, or only to ketones, or to a mixture of several carbonyl compounds (cyclohexylhydrobenzoin [4]), in which connection the formed aldehydes, and possibly also the ketones, can isomerize further in more concentrated acid to the second possible, more stable, ketone. In this consists the connection of aldehydo-ketonic rearrangement with the phenomenon of the dehydration of α-glycols. Also in support of such a statement is the fact that glycol (V) is transformed into phenylcyclohexylacetaldehyde (I) when it is reacted with dilute sulfuric acid, and into benzyl cyclohexyl ketone (II) when it is reacted with concentrated acid. The latter ketone (II) is the more stable of the two possible ketones, actually formed in our experiments from the α-oxide (IV).

The studies of S. N. Danilov [9] showed that the conditions used for the dehydration of α-glycols, and primarily the concentration of acid, determine the reaction direction; the nature of the alcohol groups and of the glycol radicals exerts a lesser influence than does the choice of dehydration agent and temperature.

In the dehydration of α-glycols, in addition to aldehydes and ketones, the products of their condensation are also formed, full glycol ethers (dioxanes), acetals of the starting glycol and the aldehyde formed from it, unsaturated hydrocarbons, etc., but α-oxides are not formed. These substances show hydration in dilute hydrochloric acid (1 : 10) at room temperature, giving here the glycols corresponding to them, but not the reverse; they isomerize either into aldehydes or into ketones, including both of the possible ketones (our case), depending on the concentration and temperature of the acid in the presence of which the isomerization occurs. Aldehydes, and the α-oxides corresponding to them in radical composition, are converted into the same more stable ketone in the presence of concentrated sulfuric acid. The oxide (IV) and aldehyde (I) studied by us also behave in a similar manner under analogous conditions. In this consists the similarity of their transformations. At the present time there is no basis to consider α-oxides, dioxanes, and three-membered and four-membered cyclic compounds as being intermediate products in the dehydration of α-glycols.

In conclusion we consider it our pleasant duty to thank E. D. Venus-Danilova, who in her time introduced us to the domain of scientific research.

EXPERIMENTAL

We obtained the starting sym. phenylcyclohexylethylene by the dehydration of phenylhexahydrobenzylcarbinol with anhydrous oxalic acid [10].

Sym. phenylcyclohexylethylene oxide (IV). To 10 g of sym. phenylcyclohexylethylene (b.p. 145-147° at 88 mm), dissolved in two volumes of anhydrous chloroform, was added in 30 minutes with cooling and stirring 632 ml of a chloroform solution of benzoyl hydroperoxide [2], containing 1.00 g of active oxygen (12% excess of hydroperoxide). After a week the amount of oxidizing agent in the reaction mixture was 10-12% of the starting amount and it failed to show further decrease. On the 10th day the chloroform solution of the reaction products was washed with dilute sodium hydroxide solution (1 : 30), water, and dried over fused potash.

As the result of removing the solvent and two vacuum-distillations we isolated 7.2 g (66.4%) of sym. phenylcyclohexylethylene oxide—a colorless liquid that did not decolorize bromine water and failed to show positive reaction for the hydroxyl and carbonyl groups.

B. p. 140-141° (6 mm), d_0^0 1.0302, d_{20}^{20} 1.0177, d_4^{20} 1.0159, n_D^{20} 1.5232, MR_D 60.85; calc. 60.50.

Found %: C 82.94, 82.81; H 9.22, 9.16. M 190, 193. $C_{14}H_{18}O$. Calculated %: C 83.11; H 8.97. M 202.

Isomerization of sym. phenylcyclohexylethylene oxide. Expt. 1. Three grams of the oxide (b.p. 140-141° at 6 mm) was heated for 50 minutes at 160-180° with pieces of pumice, larger than pea-sized, moistened with 60% sulfuric acid. The brownish liquid was diluted with ether, washed with soda solution, and dried over sodium sulfate. We isolated 1.5 g (47%) of substance with b.p. 137-139° (5 mm).

By treating 1.0 g of this substance with excess semicarbazide acetate in alcohol solution we were able to isolated 0.94 g of a semicarbazone with m.p. 191-192°, corresponding to the semicarbazone of phenylhexahydrobenzyl ketone (III) (mixed melting point) [1], which was the less soluble and deposited first, and 0.1 g of a semicarbazone (from the mother liquor) with m.p. 139-140°, corresponding to the semicarbazone of benzyl cyclohexyl ketone [1] (mixed melting point). Consequently, under the conditions of the described experiment the sym. phenylcyclohexylethylene oxide shows 90% isomerization to phenyl hexahydrobenzyl ketone and 10% isomerization to benzyl cyclohexyl ketone. The presence of phenylcyclohexylacetaldehyde among the isomerization products could not be shown.

Expt. 2. In 15 minutes 4.0 g of the oxide was added in small portions, with continuous stirring to 15 ml of concentrated sulfuric acid, cooled to -15°, and then the mixture was let stand with cooling for another 20 minutes. The thick brown-colored reaction mixture was poured over ice. The reaction products were extracted with ether, the ether extract was washed with 5% soda solution, then with water, and dried over sodium sulfate. We isolated 1.7 g (42.5%) of substance with b.p. 138-139° (5 mm).

From 1.0 g of this substance, treated with excess semicarbazide acetate, we obtained 0.99 g of the semicarbazone of benzyl cyclohexyl ketone with m.p. 139-140° (from alcohol), not depressing the melting point when mixed with the authentic semicarbazone of benzyl cyclohexyl ketone (II). Consequently in concentrated sulfuric acid the oxide of sym. phenylcyclohexylethylene is isomerized to benzyl cyclohexyl ketone.

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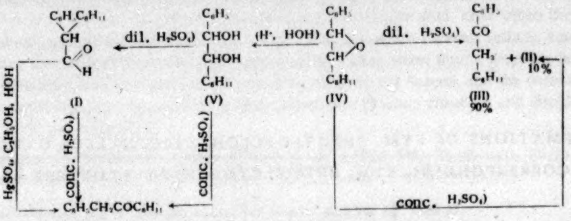
Found %: C 76.03, 76.17; H 9.10, 9.13; OH 16.16, 14.91. M 203. $C_{14}H_{20}O_2$. Calculated %: C 76.31; H 9.16; OH 15.45. M 220.



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Found %: C 76.03, 76.17; H 9.10, 9.13; OH 16.16, 14.91. M 203. $C_{14}H_{20}O_2$. Calculated %: C 76.31; H 9.16; OH 15.45. M 220.

Dehydration of sym. phenylcyclohexylethylene glycol. Expt. 1. To 10 ml of concentrated sulfuric acid, cooled to -12°, in 20 minutes, with continuous stirring, was added in small portions 1.3 g of sym. phenylcyclohexylethylene glycol. The reaction mixture became yellow at first, and then gradually assumed a brown color. In 45 minutes after adding all of the glycol the obtained quite thick mass was poured over cracked ice and allowed to stand at room temperature for 18 hours. The reaction products were extracted with ether, and the ether extract was washed with potash solution. After removal of the solvent the volatile products were steam-distilled.

As the result of the usual subsequent operations we obtained 0.8 g of light-yellow oil, which was all treated with an excess of the semicarbazide solution. Here we isolated 0.4 g of benzyl cyclohexyl ketone (II) semicarbazone with m.p. 139-140° (mixed melting point). Based on the semicarbazone the yield of ketone was 0.31 g (26%), and all of the remainder was condensation products. The semicarbazone of phenyl hexahydrobenzyl ketone was not found. The nonvolatile reaction products that failed to steam-distill were extracted with ether. From the ether extract we isolated 0.3 g of polymers, which were not studied further.

Expt. 2. A mixture of 3.8 g of the glycol and 40 ml of 25% sulfuric acid was stirred for 11 hours at 125-130° in a carbon dioxide atmosphere. The volatile reaction products were steam-distilled. Here 2.2 g of slightly yellow, clear, neutral liquid was obtained, which reacted in the cold with potassium permanganate solution, and with an ammoniacal solution of silver oxide when heated. The substance distilled at 158-160° (12 mm) and, as study revealed, proved to be phenylcyclohexylacetaldehyde [11]. Yield 1.9 g (67%). The products (0.6 g) that failed to steam-distill were isolated as a dark-yellow oil, which solidified on standing. They were not subjected to further study and probably were condensation products of the aldehyde.

SUMMARY

1. The oxide of sym. phenylcyclohexylethylene and the corresponding sym. phenylcyclohexylethylene glycol were synthesized and described for the first time.

2. Sym. phenylcyclohexylethylene oxide is hydrated in the presence of dilute hydrochloric acid to sym. phenylcyclohexylethylene glycol, and with pieces of pumice, moistened with 60% sulfuric acid, at 160-180° it shows 90% isomerization to phenyl hexahydrobenzyl ketone and 10% isomerization to benzyl cyclohexyl ketone; with concentrated sulfuric acid in the cold the oxide is transformed only to benzyl cyclohexyl ketone.

3. When heated with 25% sulfuric acid sym. phenylcyclohexylethylene glycol forms phenylcyclohexylacetaldehyde, and with concentrated sulfuric acid in the cold it gives benzyl cyclohexyl ketone, which it is impossible not to associate with the earlier mentioned isomerization of phenylcyclohexylacetaldehyde into the same ketone.

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POLYMETHYLENE CYCLES*

XXIII. SYNTHESIS AND TRANSFORMATIONS OF THE DIHYDRAZONES OF CYCLOHEXANE- AND CYCLOPENTANEDIONES

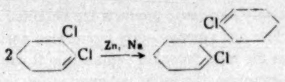
N. A. Domnin and N. S. Glebovskaya

In a series of studies on the problem of the distribution of multiple bonds in polymethylene cycles we established a number of facts that have as yet failed to receive elucidation.

In particular, we had shown that the reaction of 2,3-dichloro-1-cyclohexene with metallic sodium completely failed to give, as was to be expected, either 1,2-cyclohexadiene or its isomerization product, 1,3-cyclohexadiene. As a result of this reaction there is formed depending on the reaction conditions, either chlorine-containing dimeric, or chlorine-free polymeric products [1]. The reaction of metallic sodium with 1,2-dibromo-1-cyclohexene also fails to yield monomeric products [2].

We explained these facts by the assumption that under the influence of metallic sodium either the starting unsaturated chlorides and bromides themselves underwent polymerization, or else it was the unsaturated diene hydrocarbons formed from them.

At the same time we established that the reaction of 1,2-dichloro-2-cyclohexene with zinc dust and metallic sodium yields bis-2,2'-dichloro-1,1'-dicyclohexenyl.



Its formation can be more validly explained with the aid of the Würtz-Fittig synthesis, where two molecules of 1,2-dichlorocylohexene are fused as the result of the elimination of the two chlorine atoms at the single bond.

It was found that zinc is incapable of removing the chlorines from bis-2,2'-dichloro-1,1'-dicyclohexenyl, while metallic sodium removes the chlorines and converts it into a polymeric product (tetramer, hexamer, etc.), devoid of chlorine and corresponding to the composition $(C_6H_8)_n$.

This gives basis to assume that the reaction of unsaturated chlorides and bromides with metallic sodium and zinc proceeds by a radical mechanism.

However, of greatest interest to us is the question of whether during the progress of the discussed reactions the unsaturated monomeric forms of the hydrocarbons are formed as intermediate forms, or whether they completely fail to form?

In accord with the theories expressed by A. E. Favorsky [3] it becomes possible to make the following postulations. If during the progress of the indicated reactions either acetylene or allene hydrocarbons are formed as intermediate products, then their isomerization into diene hydrocarbons should be realized through a shifting of the hydrogen atoms from the methylene groups, found in either the α- or β-position to the hydrocarbon atoms, to which position the hydrogen atoms shift.

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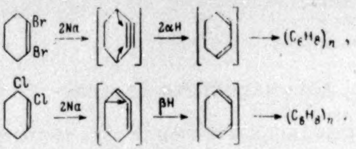
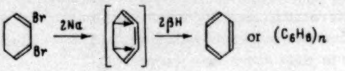
* This new name for the theme of our studies is a continuation of the theme "Studies of Unsaturated Cyclic Hydrocarbons and Their Halo Derivatives."



In order to justify such an assumption with respect to our cases it was necessary to run the reaction of cleaving two halogen atoms on such a compound, which would as the result of the subsequent isomerization of an unstable molecule with triple or cumulated bonds be converted into a stable molecule with diene bonds, incapable of undergoing polymerization, for example, into benzene.

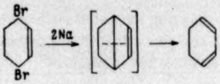
For this purpose we studied the reaction of 2,3-dibromo-1,3-cyclohexadiene with metallic sodium by the scheme [4]:



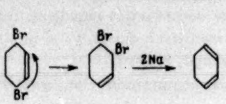
Here it was shown that there is absolutely no formation of benzene, and the reaction proceeds quantitatively in the direction of forming the polymeric product of composition $(C_6H_4)_n$.

As a result, for all of the cases discussed here it was shown that metallic sodium is capable of completely removing the halogen atoms, but that only polymeric products are obtained as the final reaction products. Consequently, it is impossible to give a clear and synonymously interpreted answer to the question of the mechanism of the discussed transformations, but as the most probable explanation it can be assumed that it is the starting unsaturated chlorides and bromides themselves that suffer polymerization under the influence of metallic sodium.

The fact established by us that 1,3-cyclohexadiene is formed in the reaction of 1,4-dibromo-2-cyclohexene with metallic sodium [5] can also serve in support of this:



To be sure, here the reaction course can be interpreted in two ways: either the bridge in the 1,4-position of the temporarily formed bicycle is cleaved and there is direct redistribution of the multiple bonds with the formation of the more stable 1,3-cyclohexadiene system, or, considering the possibility of preliminary allylic rearrangement of one of the bromine atoms in the unsaturated dibromide, there is subsequent removal of the two bromine atoms found on the adjacent carbon atoms with a simple bond, as a result of which the same 1,3-cyclohexadiene is formed.

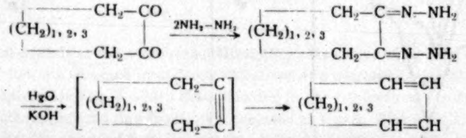


Actually, in this connection 1,3-cyclohexadiene was obtained and characterized, and consequently did not suffer polymeric transformation under the influence of metallic sodium. From this it follows that even if they had been formed as the reaction result of the unsaturated chlorides and bromides with metallic sodium, also in the above mentioned cases the diene hydrocarbons should not have undergone polymerization.

However, together with this the main problem as to the distribution of multiple bonds in cyclic compounds does not lose its theoretical significance. Consequently, it seemed both real and interesting to us to study this problem with the aid of other, more suitable methods, which would eliminate those reaction courses going in the direction of polymerization and would lead to the formation of monomeric products. For this purpose it seemed most expedient to us to use the method of decomposing the dihydrazones of cyclic diketones. Blomquist [6] and Prelog [7] made use of this method to introduce the triple bond into eight-, nine- and ten-membered rings.

We postulated that in the decomposition of the dihydrazones of 1,2-, 1,3- and 1,4-cyclohexanediones and of 1,2-cyclopentanedione the temporarily formed cycles with either acetylene or allene bonds will undergo isomerization into diene hydrocarbons with a shifting of the hydrogen atoms into either the α- or β-position.

It was proposed to run the study in accord with the scheme



However, even the first portion of the work—the preparation of the dihydrazones of the cyclopentane- and cyclohexanediones, not described up to now in the literature,—proved difficult and gave extremely interesting results. Thus, the dihydrazones of 1,2-cyclopentanedione and 1,4-cyclohexanedione are obtained with comparative ease. We were able to obtain the crystalline dihydrazone of 1,2-cyclohexanedione only once. Numerous attempts made to repeat this synthesis proved unsuccessful. Only a viscous yellowish oil was obtained, which failed to crystallize and decomposed when vacuum-distilled. 1,3-Cyclohexanedione and 5,5-dimethyl-1,3-cyclohexanedione (dimedon) do not form dihydrazones. When reacted with hydrazine hydrate, both 1,3-cyclohexanedione and dimedon form stable crystalline products, but in their composition they fail to correspond to the formulas of the dihydrazones.

We used infrared spectroscopy to confirm the nature of the obtained compounds. From the literature data on the infrared spectra of amines, hydrazine and substituted and unsubstituted amides it follows that the absorption maxima, corresponding to the valence oscillations of the N-H bond, lie in the 3μ region [8, 9]. We used an LiF prism to study the absorption spectra of the reaction products of 1,3-cyclohexanedione, dimedon (Fig. 3), 1,4-cyclohexanedione and 1,2-cyclopentanedione with hydrazine hydrate in the 3μ region (Fig. 1). The spectra were taken with an IKS-11 apparatus. The substances were taken in vaseline oil. Since the spectra of the dihydrazones had not been studied up to now, for comparison and to confirm the structure of the obtained compounds we also took in the same region the spectra of some substances of known structure, already described in the literature, and namely: the dihydrazones of diacetyl (Fig. 1), 3,5-dimethylpyrazole and 1,3,5-trimethylpyrazole (Fig. 2).

As was to be expected, the normal dihydrazones with NH_2 groups show two absorption maxima: at about 3μ and at about 3.15μ which corresponds to two valence oscillations around the N-H bond. In a pyrazole with the NH group one maximum is found at 3.15μ, while in a substituted pyrazole this maximum disappears. From this it can be seen that all normal hydrazones and dihydrazones should show two absorption maxima in the 3μ region. The reaction products of 1,3-cyclohexanedione and of dimedon with hydrazine hydrate completely fail to show any absorption in the 3μ region. Consequently, we can truthfully say that these compounds have neither the NH_2 group nor the NH group in their composition. It could be postulated that two or several molecules of the formed hydrazones, evolving ammonia, suffer fusion and give complex polymeric products. However, up to now we have been unable to determine the molecular weight of the obtained compounds; for this reason the question as to the structure of the reaction products of 1,3-cyclohexanedione and of dimedon with hydrazine hydrate still remains unanswered.

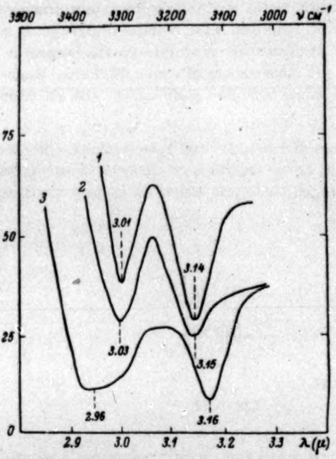


Fig. 1. Infrared spectra.
1) dihydrazone of 1,4-cyclohexanedione, 2) dihydrazone of diacetyl, 3) dihydrazone of 1,2-cyclopentanedione.

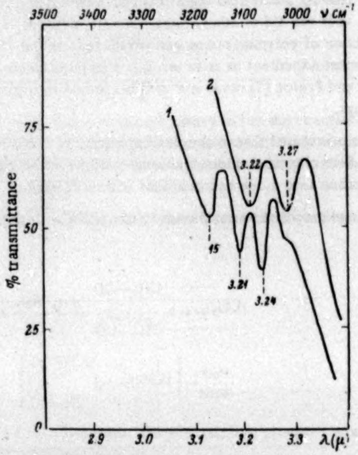


Fig. 2. Infrared spectra.
1) dimethylpyrazole, 2) 1,3,5-trimethylpyrazole.

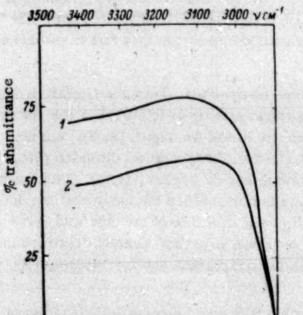


Fig. 3. Infrared spectra.
1) reaction product of dimedon with hydrazine hydrate, 2) reaction product of 1,3-cyclohexanedione with hydrazine hydrate.

We believe that the difference in the behavior of the 1,2-, 1,3- and 1,4-cyclohexanediones can be explained only if we proceed from the stereochemistry of a six-membered ring and the steric factors that originate in it as the result of the presence of substituents. In recent years a large number of papers by numerous investigators [10, 11] has been devoted to the stereochemistry of cyclohexane and its derivatives. At the present time a generally accepted and fully justified model for the six-membered ring is the symmetrical or chair-shaped form of Sachse-Mohr (Fig. 4). In this model the six carbon atoms of the ring lie in two parallel planes: the 1,3,5 carbons in the upper plane, and the 2,4,6 in the lower plane. The distance between these planes is equal to 0.5 A. Six of the cyclohexane bonds, designated by the letter a in Fig. 4, are termed "axial," three of them directed upward, and three of them downward, but all six being directed parallel to the trigonal axis of ring AB. Many authors up to now prefer to call these six bonds either "polar" or "pole" and use the letter p to designate them. The other six bonds are termed equatorial and are designated by the letter e ; they are directed in an external direction from the ring and form an angle of 109°28' with its trigonal axis.

If in the model of Fig. 4 the 1st carbon atom is turned downward, and the 4th is turned upward, then the same chair-shaped form is obtained, only now the axial bonds are transformed into equatorial, and the equatorial bonds are transformed into axial (conversion of the ring). With further study of the stereochemistry of the dihydrazones obtained by us we assume for the starting model the form depicted in Fig. 4. It is necessary to bear in mind that in this form the 2nd and 6th, and the 3rd and 5th, carbon atoms are fully equivalent.[*]

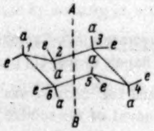


Fig. 4.

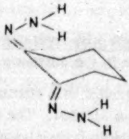


Fig. 5

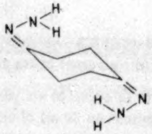


Fig. 6.

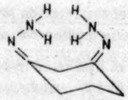


Fig. 7.

From the presented models of the cyclohexanedione dihydrazones it can be seen that the two N-NH_2 groups, standing in the 1,2-position, are directed in different directions at a considerable angle, one upward, and the other downward, as is depicted in Fig. 5, while those standing in the 1,4-position are directed in opposite directions at the ends of the six-membered ring itself, as is depicted in Fig. 6. Both groups, standing in the 1,2- and the 1,4-positions, are spatially removed from each other. Here this separation of the two groups in the 1,2- and 1,4-positions is increased even more due to the fact that the carbon atoms in the 1,2- and 1,4-positions, retaining them, lie in different planes, the distance between which is equal to 0.5 A.

The same two N-NH_2 groups, when they stand in the 1,3-position are found to have an entirely different relationship, i.e., here the 1st and 3rd carbon atoms are found to lie in one plane. In this case, in the dihydrazones of 1,3-cyclohexanedione and dimedon the two N-NH_2 groups, lying in one plane, the hydrogen atom e at the 2nd carbon atom and the hydrogen atom a (the methyl group in the case of dimedon) at the 5th carbon atom densely fill the area in the region of the three neighboring carbon atoms (Fig. 7). They cannot find a place without jostling each other, which is responsible for the creation of steric hindrance in the molecules of the dihydrazones of 1,3-cyclohexanedione and dimedon.

On the one hand, a deviation of the N-NH_2 groups from their normal positions, being due to the jostling of these groups, increases the store of energy in the molecule and in that way decreases its stability; on the other hand, due to their closeness, the N-NH_2 groups react with each other, and evolving ammonia, give products of as yet unknown structure.

As a result, the possibility of forming the dihydrazones of the 1,2-, 1,3- and 1,4-cyclohexanediones and their stability are found to be in full accord with the representation that the cyclohexane ring is chair-shaped.

Due to the planarity and solid construction of the five-membered ring, 1,2-cyclopentanedione easily gives a stable dihydrazone.

EXPERIMENTAL

Synthesis of 1,2-cyclohexanedione dihydrazone. 1,2-Cyclohexanedione was obtained by the oxidation of cyclohexanone with selenious anhydride [12].

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[*] To this should be added the fact that actually during the process of reacting the cyclohexanediones with hydrazine it is possible for the chair-shaped form to migrate into a tub-shaped form. We intentionally simplifiy the explanation of the obtained facts, proceeding from the chair-shaping form as being the more stable.

To a solution of 5 g of the diketone in 20 ml of anhydrous alcohol at room temperature and with stirring was added a solution of 4.46 g (2 moles) of hydrazine hydrate in 10 ml of anhydrous alcohol. A white precipitate began to deposit after half of the taken hydrazine hydrate was added, which disappeared with further addition of the hydrazine hydrate. Removal of the solvent gave 4.5 g (72%) of colorless, transparent, prismatic crystals. After recrystallization from alcohol, m.p. 63-64°.

Found %: N 39.89, 40.07. $C_6H_{12}N_4$. Calculated %: N 40.00.

We were unable to obtain even the monohydrazone of 1,2-cyclohexanedione. The reaction of one mole of hydrazine hydrate with the diketone gave a precipitate, which resinified even during filtration. The dihydrazone of the 1,2-cyclohexanedione is probably formed, which with an excess of the diketone gives an unstable ketazine.

Synthesis of the reaction product of 1,3-cyclohexanedione with hydrazine hydrate. 1,3-Cyclohexanedione was obtained by the hydrogenation of resorcinol under pressure in the presence of Raney nickel [13].

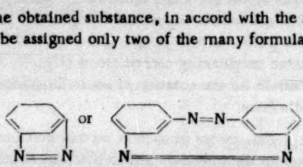
To 18 ml of hydrazine hydrate in 20 ml of anhydrous alcohol with stirring and ice-cooling was added a solution of 10 g of 1,3-cyclohexanedione in 50 ml of anhydrous alcohol. The removal of the solvent in vacuo under slight heating (30-40°) gave crystals. Two recrystallizations from alcohol gave white, lustrous, needle-shaped crystals, which did not melt but decomposed at around 200°. The crystals are difficultly soluble in alcohol, benzene and water, and insoluble in ether. They fail to change on standing. From 10 g of the diketone we were able to isolate only 1.5 g of the reaction product with hydrazine.

Found %: C 67.68, 67.82; H 5.76, 5.88; N 26.86, 27.05. $C_6H_6N_2$. Calculated %: C 67.92; H 5.66; N 26.42.

Hydrazone $C_6H_{12}N_4$. Calculated %: C 51.42; H 8.57; N 40.00.

These analysis data correspond to a substance with composition either $C_6H_6N_2$ or $C_{12}H_{12}N_4$. This substance could have been formed only as the result of removing 2 moles of ammonia from 1 mole of the dihydrazone or, correspondingly, of 4 moles of ammonia from 2 moles of the dihydrazone.

In view of the fact that the obtained substance, in accord with the infrared spectra, contains neither the NH- nor the NH_2-group, it can be assigned only two of the many formulas possible for it



Up to now we have not been able to determine the molecular weight of this substance, since it is soluble in benzene only at the boil, while in general it is insoluble in camphor.

In studying the absorption spectra of the reaction product of 1,3-cyclohexanedione with hydrazine hydrate in the infrared region we were unable to detect any absorption maxima corresponding to the groups NH and NH_2. A LiF prism was used for the spectra in the 2-4μ region, and a NaCl prism in the 2-14μ region.

Synthesis of the reaction product of dimedon with hydrazine hydrate. To 8 ml of hydrazine hydrate in 10 ml of anhydrous alcohol with stirring and ice-water cooling was added a solution of 5 g of dimedon in 60 ml of anhydrous alcohol. The solvent was removed in vacuo without heating. Crystals began to deposit after standing for several days. From 5 g of dimedon we were able to obtain a total of 0.8 g of its reaction product with hydrazine hydrate. After recrystallization from alcohol it was obtained as pale yellow, colorless, regularly shaped crystals. M.p. 268° (decompn.). Difficultly soluble in alcohol and benzene, and insoluble in water, ether, chloroform and bromoform.

Found %: C 71.18, 71.36; H 7.45, 7.53; N 20.75, 20.82. $C_8H_{10}N_2$. Calculated %: C 71.64; H 7.46; N 20.89.

The data of the given analyses show that the reaction product of 5,5-dimethyl-1,3-cyclohexanedione (dimedon) with hydrazine corresponds to a substance with composition $C_8H_{10}N_2$ or $C_{16}H_{20}N_4$. This substance could have been formed either as the result of removing 2 moles of ammonia from 1 mole of the dimedon dihydrazone or of 4 moles of ammonia from 2 moles of the dihydrazone.

In view of the fact that this substance contains neither NH- nor NH_2-groups, then it also can be assigned only two of the many formulas possible for it, similar to those that had been proposed for the reaction product of 1,3-cyclohexanedione with hydrazine.

In studying the absorption spectra of the reaction product of dimedon with hydrazine hydrate in the infrared region we were unable to detect an absorption maxima corresponding to the groups NH and NH_2. A LiF prism was used to take the spectra in the 2-4μ region, and a NaCl prism in the 2-11μ region.

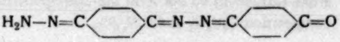
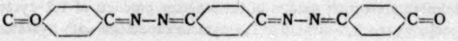
Synthesis of 1,4-cyclohexanedione dihydrazone. 1,4-Cyclohexanedione was obtained from diethyl succinylsuccinate by heating it with water in an ampul at 200° [14].

To 7 ml of hydrazine hydrate (4 moles) in 10 ml of anhydrous alcohol with stirring and ice-water cooling was added a solution of 3.5 g of the diketone in 60 ml of anhydrous alcohol. The solvent was removed in vacuo under slight heating (40-50°). Removal of solvent immediately gave 4.15 g (95%) of the dihydrazone as a precipitate.

The dihydrazone of 1,4-cyclohexanedione is readily soluble in water and alcohol, difficultly soluble in benzene, and insoluble in ether. It was purified by vacuum-distillation at 60° (5 mm), m.p. 112°.

Found %: N 40.22, 40.21. $C_6H_{12}N_4$. Calculated %: N 40.00.

Reaction product of one mole of 1,4-cyclohexanedione with one mole of hydrazine hydrate. To a solution of 1 g of the diketone in 50 ml of anhydrous alcohol with stirring and ice-cooling was added a solution of 0.5 g of hydrazine hydrate in 10 ml of anhydrous alcohol. A grayish precipitate began to deposit after all of the hydrazine hydrate had been added, which failed to disappear with further stirring. The precipitate was filtered, washed with alcohol, and dried; it does not melt but decomposes at 200°, and is insoluble in water, alcohol, ether and benzene.

It is probable that here the 1,4-cyclohexanedione dihydrazone is formed at the start, which with excess diketone can give either the monosubstituted hydrazoketazine  (I), or the disubstituted ketazine  (II).

Found %: C 61.52, 61.24; H 7.42, 7.33; N 23.64, 23.83.
(I) Calculated %: C 61.55; H 7.69; N 23.93.
(II) Calculated %: C 65.86; H 7.32; N 17.07.

The absorption spectrum of the monosubstituted hydrazoketazine was studied in the infrared region (Fig. 8). The 2-4μ region was taken on a LiF prism and the 2-7μ region on a NaCl prism. A domestic IKS-11 spectrometer was used to take the spectra. The pattern of the substance was taken in vaseline oil. The absorption spectrum supports the hydrazoketazine structure. Thus, absorption maxima were found at 2.98 and 3.12μ, which characterizes, without doubt, the NH_2 group, and an absorption maximum at 6.07μ, corresponding to the frequency of the carbonyl group.

Synthesis of 1,2-cyclopentanedione dihydrazone. 1,2-Cyclopentanedione was obtained by the chlorination of cyclopentanone [15], saponification of the chloroketone and oxidation of the ketol [16].

To 10 ml of hydrazine hydrate (2 moles) in 20 ml of anhydrous alcohol was added in drops a solution of 10 g of the diketone in 50 ml of anhydrous alcohol with stirring and ice cooling. The solvent was removed in vacuo under slight heating (40-45°). The residue crystallized when the solvent was removed. From 10 g of the diketone we obtained 11.9 g (93%) of the dihydrazone with m.p. 85-86°. Readily soluble in water and alcohol, more difficultly soluble in benzene, and insoluble in ether. After recrystallization from benzene, m.p. 89-90°.

Found %: N 44.68, 44.36. $C_5H_{10}N_4$. Calculated %: N 44.44.

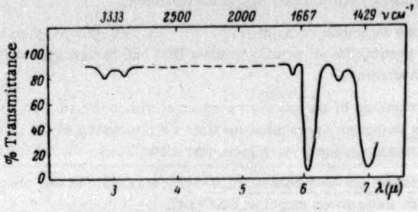


Fig. 8. Infrared spectrum of the hydrazoketazine.

The dihydrazone is unstable, and rapidly decomposes even when stored in ampuls.

Attempts to obtain the monohydrazone of 1,2-cyclopentanedione proved unsuccessful. The reaction of 1 mole of hydrazine hydrate with the diketone gave a precipitate, insoluble in alcohol, which immediately resinified. It is probable that the formed dihydrazone reacts with excess diketone, giving the ketazine, which immediately decomposes.

SUMMARY

1. The dihydrazones of 1,2-cyclopentanedione and of the 1,2- and 1,4-cyclohexanediones were synthesized and characterized for the first time.

2. It was shown that 1,2-cyclopentanedione and 1,2-cyclohexanedione do not give monohydrazones, while 1,4-cyclohexanedione with 1 mole of hydrazine hydrate gives the hydrazoketazine.

3. It was shown that 1,3-cyclohexandione and its similarly constructed 5,5-dimethyl-1,3-cyclohexanedione (dimedon) do not form the corresponding dihydrazones, but give stable crystalline products of respective composition $C_6H_6N_2$ and $C_8H_{10}N_2$.

4. The infrared absorption spectra of the reaction products of 1,2-cyclopentanedione, of the 1,3- and 1,4-cyclohexanediones and 5,5-dimethyl-1,3-cyclohexanedione with hydrazine hydrate were studied in the 3μ region.

5. Theories were expressed, giving a qualitative explanation of the obtained facts in the light of the stereochemistry of five- and six-membered rings and of steric hindrance factors.

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POLYMETHYLENE CYCLES

XXIV. REACTION OF CYCLOPENTANE- AND CYCLOHEXANEDIONES WITH DIMETHYLHYDRAZINE

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In the previous communication [1] we showed that it was quite easy for us to synthesize the dihydrazones of 1,2-cyclopentanedione and of 1,2- and 1,4-cyclohexanediones.

We were not able to obtain the dihydrazones of 1,3-cyclohexanedione and of 5,5-dimethyl-1,3-cyclohexanedione (dimedon). The reaction of these 1,3-diketones with hydrazine yields extremely stable crystalline products, but they correspond to neither the monohydrazones nor the dihydrazones in their composition. These facts lead to the postulation that the instability shown by the dihydrazones of 1,3-cyclohexanedione and of dimedon is due to the fact that the two reactive N-NH_2 groups in them react with each other, and evolving ammonia, are converted into bicyclic compounds, simultaneously containing either carbocyclic or aromatic rings and heterocyclic rings. As is known, such systems are unstable and either isomerize or migrate into polymeric products. The possibility of the reactive N-NH_2 groups showing interaction in the case of the 1,3-cyclohexanediones we explained as being due to the fact that in the 1,3-position these groups are closer to each other than when they are in the 1,2- and 1,4-positions, which follows from the chair-shaped form of cyclohexane.

To verify this postulation it was necessary to eliminate the possibility of the N-NH_2 groups showing interaction. Consequently, we replaced the two active hydrogen atoms of one of the amino groups in hydrazine by methyl radicals, and then reacted all of the diketones with the unsymmetrically substituted dimethylhydrazine. As a result of the performed experiments it was found that 1,2-cyclopentanedione and the 1,2- and 1,4-cyclohexanediones easily give the corresponding monodimethylhydrazones and bisdimethylhydrazones, which were prepared and characterized by us. It proved surprising that 1,3-cyclohexanedione and 5,5-dimethyl-1,3-cyclohexanedione (dimedon) behaved differently toward dimethylhydrazine. Both of these diketones give only the corresponding monodimethylhydrazones with m.p. 142-143° and 164°, but completely fail to give the bisdimethylhydrazones.

We believe that the different behavior shown by the 1,2-, 1,3- and 1,4-cyclohexanediones in the reaction with 1,1-dimethylhydrazine can be explained only if we proceed from the stereochemistry of the six-membered ring.

In the previous communication we presented molecular models of the dihydrazones of the 1,2-, and 1,3- and 1,4-cyclohexanediones, and also of dimedon. If in these models the N-NH_2 groups are replaced by N-N$(CH_3)_2$ groups, then the newly obtained models will correspond to the structure of the molecules of the bisdimethylhydrazones of 1,2- and 1,4-cyclohexanediones, and also of 1,3-cyclohexanedione and dimedon. From these models it can plainly be seen that for the dihydrazones of the 1,2- and 1,4-cyclohexanediones a replacement of the N-NH_2 group by the N-N$(CH_3)_2$ group will not have any essential significance, since in these cases both the N-NH_2 groups and the N-N$(CH_3)_2$ groups are quite distant from each other in space. A replacement of the N-NH_2 group by the N-N$(CH_3)_2$ group in the hydrazones and dihydrazones of 1,3-cyclohexanedione and of dimedon will already possess essential significance. In these cases the two N-N$(CH_3)_2$ groups, found at carbon atoms 1 and 3, lying in one plane, should themselves also be found in one plane and should more densely fill the space in the region of the 1st, 2nd and 3rd carbon atoms. Proceeding from these considerations, it could be expected that 1,3-cyclohexanedione and dimedon should either give the bisdimethylhydrazones with considerably greater difficulty or should not give the same at all. This prediction was confirmed by us experimentally.

We assume that since only one of the two carbonyl groups in either 1,3-cyclohexanedione or dimedon reacted with dimethylhydrazine, then in the formed monodimethylhydrazone the second carbonyl group proves to be concealed, i.e., it is screened by the entrant N-N(CH$_3$)$_2$ group, by e – the hydrogen atom at the 2nd carbon atom, and by a – the hydrogen atom (in the case of dimedon a is the methyl group) at the 5th carbon atom (Figs. 1 and 2).

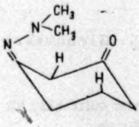

Fig. 1.

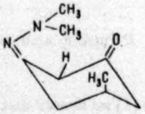

Fig. 2.

As the result of filling the space in the region of the 1st, 2nd and 3rd carbon atoms in the molecules of the monodimethylhydrazones of 1,3-cyclohexanedione and dimedon there arise steric hindrance factors, as a result of which the discussed monodimethylhydrazones lose their ability to react with a second molecule of dimethylhydrazine.

The theoretical considerations discussed by us and the obtained facts are in accord with the studies of Kapon, Cianolon and Cornubert [2] on the mutual influence exerted by atoms in simple cyclohexane molecules. Thus, these authors came to the conclusion that in α-methylcyclohexanol the distance between OH$_1$ of the a-group and the hydrogen atoms H$_3$ a and H$_5$ a is smaller (2.55 A) than the distance between the same OH$_1$ of the e-group and the hydrogen atoms H$_2$ a and H$_6$ a (2.74 A).

We believe that as new facts accumulate in the field being studied by us the qualitatively described steric hindrance phenomena can be given a quantitative description.

EXPERIMENTAL

We described the preparation of the 1,2-, 1,3- and 1,4-cyclohexanediones and of 1,2-cyclopentanedione in the previous communication [1]. In this paper we give the data on the preparation, physical constants and properties of the mono- and di-dimethylhydrazones of the corresponding cyclic diketones.

Monodimethylhydrazone of 1,2-cyclohexanedione. To a solution of 1,2-cyclohexanedione (1 mole) in anhydrous alcohol with constant stirring and ice cooling was added a solution of an exactly calculated amount of 1,1-dimethylhydrazine (1 mole) in anhydrous alcohol. After all of the dimethylhydrazine had been added the reaction mixture was stirred for another hour. Then the solvent was vacuum-distilled with slight heating. The residue was vacuum-distilled. The distillate was a yellow mobile liquid, rapidly darkening, even when stored in an ampul. Yield 37%.

B.p. 86-87° (7 mm), d_4^{20} 1.0532, n_D^{20} 1.5155, MR 44.19; calc. 43.57.

Found %: N 18.52, 18.30. $C_8H_{14}ON_2$. Calculated %: N 18.18.

Bisdimethylhydrazone of 1,2-cyclohexanedione. To a solution of 2 moles of dimethylhydrazine in anhydrous alcohol with stirring and cooling was added a solution of 1mole of 1,2-cyclohexanedione in anhydrous alcohol. The solution was immediately vacuum-distilled. Yield 50%.

B.p. 109-110° (3 mm), d_4^{20} 0.9846, n_D^{20} 1.5243, MR 61.08; calc. 59.41.

Found %: N 28.98, 28.62. $C_{10}H_{20}N_4$. Calculated %: N 28.57.

Monodimethylhydrazone of 1,3-cyclohexanedione. To a solution of 2 moles of dimethylhydrazine in anhydrous alcohol with stirring and strong cooling (ice and salt) was added a solution of 1 mole of 1,3-cyclohexanedione in anhydrous alcohol. The solvent was removed in vacuo without heating. Crystals deposited from the residue. They could be purified only by vacuum-distillation at 150° (10 mm). M. p. 142-143°.

Found %: C 61.54, 62.36; H 9.28, 9.29; N 18.46, 17.92. $C_8H_{14}ON_2$. Calculated %: C 62.34; H 9.02; N 18.18.

A change in the reaction conditions (increase in the amount of dimethylhydrazine, elevation of the reaction temperature) does not lead to the formation of the bisdimethylhydrazone, but lowers the yield of the monodimethylhydrazone.

Monodimethylhydrazone of 5,5-dimethyl-1,3-cyclohexanedione (dimedon). To a solution of 2 moles of dimethylhydrazine in anhydrous alcohol with stirring and at room temperature was added a solution of 1 mole of dimedon in anhydrous alcohol. The solvent was removed in vacuo under slight heating (35-40°). A yellow crystalline mass remained in the flask. Recrystallization from anhydrous alcohol gave very faintly yellow crystals, insoluble in benzene, and with m.p. 162-163°. Yield 30%.

Found %: C 65.76, 65.65; H 10.09, 10.04; N 15.48, 15.60. M 184.3 (Rast). $C_{10}H_{18}ON_2$. Calculated %: C 65.94; H 9.89; N 15.38. M 182.

Bisdimethylhydrazone of 1,4-cyclohexanedione. To a solution of 2 moles of dimethylhydrazine in anhydrous alcohol with stirring and at room temperature was added a solution of 1 mole of the diketone in anhydrous alcohol. The solvent was immediately removed in vacuo with slight heating (30-40°). A dark crystalline mass remained, which was extremely soluble in alcohol, ether and benzene. The compound could not be purified by recrystallization, for which reason it was vacuum-distilled at 55° (2 mm); m.p. 63-65°.

Found %: N 28.82, 28.73. $C_{10}H_{20}N_4$. Calculated %: N 28.57.

Monodimethylhydrazone of 1,2-cyclopentanedione. To a solution of 1 mole of the diketone in anhydrous alcohol with stirring and water cooling was added a solution of the exactly calculated amount (1 mole) of dimethylhydrazine in anhydrous alcohol. After the solvent was removed in vacuo with slight heating the residue was distilled twice. Yield 23%.

B.p. 74-75° (2 mm) d_4^{20} 1.0262, n_D^{20} 1.5122, MR 41.01; calc. 39.00.

Found %: N 20.09, 19.78. $C_7H_{12}ON_2$. Calculated %: N 19.99.

Bisdimethylhydrazone of 1,2-cyclopentanedione. To a solution of dimethylhydrazine (slightly in excess of 2 moles) in anhydrous alcohol with stirring and water cooling was added 1 mole of the diketone in alcohol at 30°. Vacuum-distillation of the residue gave a light-yellow liquid, which darkened rapidly even when kept in an ampul. Yield 21.5%.

B.p. 95-97° (1 mm), d_4^{20} 0.9864, n_D^{20} 1.5278, MR 56.79; calc. 54.79.

Found %: N 30.45, 30.97. $C_9H_{18}N_4$. Calculated %: N 30.77.

SUMMARY

1. The reaction products of the 1,2- and 1,4-cyclohexanediones and of 1,2-cyclopentanedione with one and two moles of 1,1-dimethylhydrazine were prepared and characterized.

2. It was shown that 1,3-cyclohexanedione and 5,5-dimethyl-1,3-cyclohexanedione (dimedon) give only the monodimethylhydrazones with 1,1-dimethylhydrazine.

3. Theoretical considerations were expressed relative to the different behavior shown by the 1,2-, 1,3- and 1,4-cyclohexanediones with respect to 1,1-dimethylhydrazine from the viewpoint of the stereochemistry of the six-membered ring.

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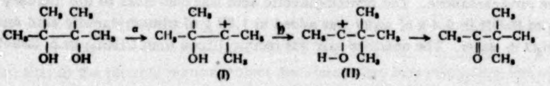
STUDY OF THE MECHANISM OF THE PINACOL REARRANGEMENT BY THE DEUTERO-EXCHANGE METHOD

D. N. Kursanov and Z. N. Parnes

At the present time it has been established that the carbonium ion is capable of entering into the hydrogen-exchange reaction with deutero acids; in this connection all of the hydrogen atoms, found on the carbon atoms adjacent to the carbonium center, show exchange [1]. We postulated that this property of carbonium ions can be used to study the mechanisms of various reactions in organic chemistry, so as to establish whether the reaction proceeds through the formation of the intermediate carbonium ion.

The first reaction which we undertook to study was the pinacol rearrangement.

A substantial number of the studies, devoted to the pinacol rearrangement, give an ionic interpretation of its mechanism.



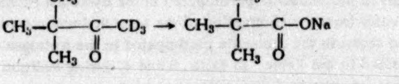
$$CH_3-\underset{OH}{\overset{CH_3}{C}}-\underset{OH}{\overset{CH_3}{C}}-CH_3 \xrightarrow{a} CH_3-\underset{OH}{\overset{CH_3}{C}}-\underset{CH_3}{\overset{+}{C}}-CH_3 \xrightarrow{b} CH_3-\underset{H-O}{\overset{+}{C}}-\underset{CH_3}{\overset{CH_3}{C}}-CH_3 \longrightarrow CH_3-\underset{\overset{\|}{O}}{C}-\underset{CH_3}{\overset{CH_3}{C}}-CH_3$$

However, on the basis of the stereochemical studies made of the pinacol rearrangement of aminoalcohols [2], and then of the pinacol rearrangement of cis- and trans-1,2-dimethyl-1,2-cyclohexanediol [3], it was concluded that stages "a" and "b" proceed simultaneously.

We made the assumption that the ability of carbonium ions to enter into the hydrogen-exchange reaction would permit an independent method of directly establishing whether the "a" and "b" stages of the reaction proceed in sequence or simultaneously. For this we studied the pinacol rearrangement of pinacol under the influence of deuterosulfuric acid. In this case, if the carbonium ions (I) and (II) were formed, then 9 hydrogen atoms would enter into the exchange; 6 in carbonium ion (I) and 3 in carbonium ion (II).

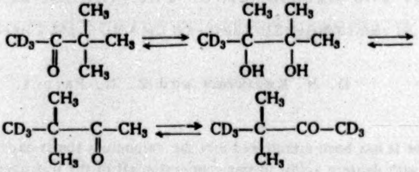
In this case, if stages "a" and "b" proceed simultaneously, D does not enter the tert-butyl group. The presence of D could be expected only in the CH_3-group, on the basis of the earlier established capacity for exchange shown by the hydrogen atoms attached to the α-carbon atom in saturated ketones [1].

Our experiments revealed that in running the pinacol rearrangement with D_2SO_4 the pinacol that was formed contained only three exchanging hydrogen atoms. The oxidation of this pinacol with bromine on the alkaline side gave us a trimethylacetic acid that was practically devoid of deuterium. Consequently, all of the deuterium found in the pinacol molecule, was in the methyl, and not in the tert-butyl group.



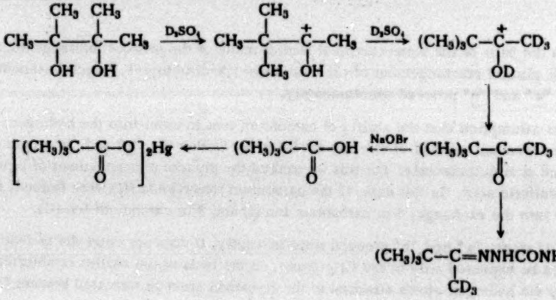
$$CH_3-\underset{CH_3}{\overset{CH_3}{C}}-\underset{\overset{\|}{O}}{C}-CD_3 \rightarrow CH_3-\underset{CH_3}{\overset{CH_3}{C}}-\underset{\overset{\|}{O}}{C}-ONa$$

As a result, a study of the hydrogen exchange reaction failed to give any position indications as to the intermediate formation of the carbonium ion (I). The absence of deuterium in the tert-butyl group suggests that either the carbonium ion (I) is never formed in the rearrangement, or that the carbonium ion (I) is formed, but it is so short-lived that hydrogen exchange fails to take place to any appreciable extent. This is found to be in agreement with the stereochemical data and signifies that cleavage of the CH_3-group and migration of the radical proceed simultaneously for all practical purposes. Our data also show that the reaction is irreversible under the experimental conditions used. Actually, if the reaction were reversible, then the tert-butyl group would contain deuterium:



EXPERIMENTAL

The experiments on the pinacol rearrangement were run with anhydrous pinacol and 100% D_2SO_4 (excess density was 89,000 γ/ml). The D_2SO_4 was gradually added to the pinacol, cooled with ice water. After 1 hour the reaction mixture was poured into 10% $NaHCO_3$ solution, extracted with ether, and distilled. The fraction with b.p. 102-106° was collected. Part of the fraction was oxidized to trimethylacetic acid, and another part was converted to the semicarbazone. The trimethylacetic acid was converted to the mercury salt [4]. For this a solution of 0.71 g of NaOH in 6.4 g of water was added to 1.82 g of trimethylacetic acid and a solution of 6 g of $Hg(NO_3)_2 \cdot \frac{1}{2}H_2O$ in water. The obtained salt was recrystallized from $CHCl_3$; m.p. 233-234°.



The presence of deuterium in the pinacol was determined by the excess density of the water from the combustion of its semicarbazone. The presence of deuterium in the tert-butyl radical was determined by the excess density of the water from the combustion of the mercury salt of the trimethylacetic acid. Calculation of the excess density of the water from the combustion of the semicarbazone was based on the assumption that three of the hydrogen atoms in the molecule participated in the hydrogen exchange reaction. Calculation of the excess density of the water from the combustion of the trimethylacetic acid salt was based on the assumption that 6 of the hydrogen atoms in the molecule participated in the hydrogen exchange reaction. The experimental results are summarized in the Table. In Expts. 3 and 4, during addition of D_2SO_4, SO_3 was gradually added to bind the water that was liberated during the time of the experiments.

Expt. No.	Amount (in g)		Excess density of the combustion water					
			calculated γ/ml)		experimental			
					semicarbazone		salt	
	pinacol	D_2SO_4	semicarbazone	salt	(in γ/ml)	(in % calculated value)	(in γ/ml)	(in % calculated value)
1	14.47	13.85	5550	13.080	5630	101	115	1
2	15.00	13.92	5830	13.220	3240	55	130	1
3	14.58	14.80+6 g SO_3	5810	13.790	5120	90	485	3
4	16.18	16.8+10 g SO_3	5970	14.225	4180	70	165	1

The divergence in the figures, characterizing the degree of exchange in the CH_3-group of the pinacol semicarbazone is explained, as was shown by special experiments, by the fact that in the neutralization, the conditions of which were not rigidly standardized, exchange took place, i.e., a partial elution of deuterium from the methyl group.

This fact does not influence the conclusions derived from our study, since we judged directly from the excess density of the water from the combustion of the trimethylacetic acid salt that deuterium was absent in the tert-butyl group.

SUMMARY

It was shown that in the pinacol rearrangement the elementary acts composing this reaction, namely the cleavage of a hydroxyl and the migration of an alkyl radical, proceed simultaneously, and that the pinacol rearrangement reaction under our experimental conditions is practically irreversible.

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SYNTHESIS OF VINYL DERIVATIVES OF THE FURAN SERIES

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Vinyl derivatives of the furan series attract attention as being starting products for the preparation of new types of polymers with valuable technical properties. Methods for their preparation have been quite inadequately developed, and information as to their physiochemical properties is not fully reliable due to the absence of data on the degree of purity of the products.

Our problem in the present study was to obtain and study the properties of the vinyl derivatives of furan, benzofuran and dibenzofuran; here special attention was given to the problem of obtaining these products in the purest form possible.

2-Vinylfuran was described by Liebermann [1], who was the first to obtain it in 1894 as a water-insoluble oil by the dry distillation of furylacrylic acid. Considerably later, in 1927, Moureau, Defraisse and Johnson [2] obtained vinylfuran and made a more detailed study of its properties. In 1939 P. P. Shorygin and N. V. Shorygina [3] attempted to prepare vinylfuran by the cleavage of water, with the aid of potassium acid sulfate, from the secondary furylethyl alcohol by heating, but here the formed vinylfuran polymerized right in the distillation flask. In 1941 one of us [4] synthesized vinylfuran and some of its properties were studied. After this, vinylfuran was obtained by a number of authors [5-7], but apparently no special attempt was made to purify it. In not one of these studies was any data given on the elementary composition, the amount of vinyl group, or the amount of furylacrylic acid present as impurity.

2-Vinylbenzofuran was first obtained and described in 1951 by Elliot [8]. Further information on its preparation and properties is not encountered in the literature if the patent by Kuhn [9] on the catalytic hydrogenation of polyvinylbenzofuran in the presence of Raney nickel for the purpose of raising the softening temperature of the polymer is neglected.

2-Vinyldibenzofuran was first obtained, among other vinyl compounds, in 1946 by Mowry and co-workers [10]. Similar fragmentary data also exist in a number of patents [11-13], indicating various methods for the preparation and use of this compound. Kern and Wilson [14] described a hypothetical scheme for the preparation of the vinyldibenzofuran, indicating here only that controlling the purity of both the intermediates and the final product—the monomer—was fully satisfactory. It is indicated that the polymer of this compound served during the time of the Second World War as one of the ingredients in the composition for the replacement of mica.

The methods recommended in the literature for the synthesis of the above-indicated compounds were repeated by us, in some we introduced a number of modifications, while some of the others were completely revised by us. These changes dealt with practically all of the various synthesis steps, beginning from the preparation of the starting products and ending with the preparation, purification and methods of analyzing the final vinyl derivatives.

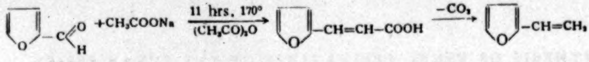
By analogy with the methods for the preparation of vinyl derivatives of the aromatic series, three basic methods can be used for the preparation of the vinyl derivatives of the furan series: 1) dehydration of the corresponding alcohols, 2) decarboxylation of the corresponding acids, and 3) dehydrogenation of the corresponding hydrocarbons.

The dehydration of carbinols is the most widely used method for the preparation of vinyl compounds. The carbinols needed for dehydration were obtained by the reduction of the corresponding ketones. The

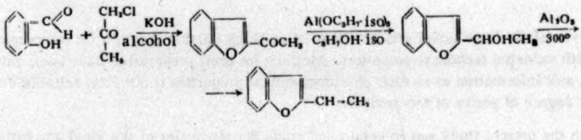
Meerwein-Ponndorf reactions, first used by us for the indicated compounds, was the main reduction process used, and in one case, for comparison, we ran the reduction in an autoclave over copper-chromium oxide catalyst.

In the present study the vinyl derivatives of the furan series were obtained by the following schemes:

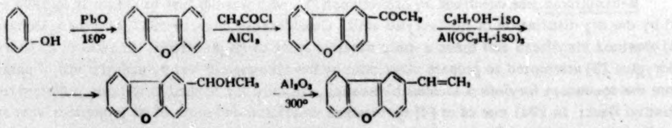
1. 2-Vinylfuran:



2. 2-Vinylbenzofuran:



3. 2-Vinyldibenzofuran:



The dehydration of carbinols over aluminum oxide was selected by us as the main method for the preparation of the vinyl derivatives of the furan series. An exception was made for the first member of this series, namely 2-vinylfuran, and it was obtained by the decarboxylation of furylacrylic acid. The latter, in turn, was obtained by the condensation of furfural with sodium acetate in the presence of acetic anhydride [4].

Acetylbenzofuran, in contrast to acetyldibenzofuran, was obtained, not by direct acetylation by the Friedel-Crafts reaction, but by the condensation of salicylaldehyde with chloroacetone in alcoholic alkaline medium. Acetyldibenzofuran was obtained by reacting acetyl chloride with dibenzofuran in benzene solution in the presence of anhydrous aluminum chloride. Dibenzofuran was obtained from phenol and lead oxide under heating. In the present study special attention was given to a careful purification of the obtained vinyl derivatives, which was necessary for a determination of their physicochemical constants and for the further study of the polymerization kinetics. The physicochemical constants of the monomers are given in the Table.

EXPERIMENTAL

2-Vinylfuran

a) 2-Furylacrylic acid was obtained by the method of [4]. Light-yellow needles with m.p. 140°, yield 95%. Found M 138.1. $C_7H_6O_3$. Calculated M 138.0.

b) Preparation of vinylfuran: in a 100-150 ml Wurtz flask was placed 100 g of furylacrylic acid, and a small amount of phenyl-β-naphthylamine and a copper spiral were added; the reaction mixture was heated very slowly on a sand bath to 250-270°. The vapors that distilled were condensed in the condenser, and the 2-vinylfuran was collected in the receiver as a clear light-colored oil. Only toward the end of the process did some water collect in the receiver. It is recommended that a mercury seal be fitted on the reaction flask so as to avoid raising the pressure in the system as the result of plugging the escape tube by the sublimed furylacrylic

Physicochemical Properties of the Monomers

Indices	2-Vinylfuran		2-Vinylbenzofuran		2-Vinyldibenzofuran	
	our data	literature data	our data	literature data	our data	literature data
Boiling point	96–97° (764 мм)	95–101° [4–7]	52° (1.6 · 10^{-1} мм)	72° (2 мм) [8]	147° (2 мм), 130° (1.6 · 10^{-1} мм)	141° (1 мм) [12], 167° (7 мм) [12], 128° (1.5 мм) [10]
Melting point	Liquid		Liquid		31°	30° [12], 38–39° [10]
Index of refraction n_D	1.5007 (20°), 1.4994 (28°)	1.5000 (28°) [6]	1.6125 (25°)	1.6125 (25°) [8]	1.6572 (25°)	1.6582 (25°) [12], 1.6597 [10]
Specific gravity d_4^{20}	0.9436, 0.9392 (28°)	0.945 [7]	1.0588	1.0598 [8]	Solid	
Molecular refraction MR_D	29.39	29.29	46.88	None	—	
Elementary composition (in %) found C . .	76.58	—	83.45	—	86.59	—
Elementary composition (in %) found H . .	6.53		5.79		5.16	
Elementary composition (in %) calculated C . .	76.57	—	83.33	—	86.54	—
Elementary composition (in %) calculated H . .	6.38		5.61		5.27	
Percent unsaturation	100.3	None	100.1	None	99.8	None

acid. The yield of crude product was as high as 50%. The crude product was washed with 20% caustic solution, then with water to neutral reaction, dried over calcium chloride, and distilled. The vinylfuran obtained after such treatment usually contained from 5 to 7% of furylacrylic acid. To completely purify the vinylfuran the major portion of the furylacrylic acid was removed by freezing. The last traces of the acid were removed by distilling the product from solid powdered potassium hydroxide at room temperature and a residual pressure of 7-10 mm.

The amount of vinylfuran in the product purified in this manner was controlled by the data of the elementary analysis and by determining the amount of vinyl group by the chloro-iodination method. The method of iodinating these compounds with iodine chloride solution was developed by us, since the methods using bromine proved unsuitable due to its addition at the double bond of the furan ring. Analysis of the product purified in this manner showed a 100.3% content of the vinylfuran.

2-Vinylfuran is a colorless mobile liquid, extremely volatile, and with an odor similar to that of styrene. It should be kept in sealed ampuls under cooling.

2-Vinylbenzofuran

a) Preparation of 2-acetylbenzofuran [8]. A solution of 100 g of salicylaldehyde in 400 ml of ethyl alcohol was heated (in a 1.5 liter flask) with an alcoholic solution of 50 g of potassium hydroxide until complete solution had been achieved and the solution became clear. To the obtained solution was slowly added the calculated amount of chloroacetone (75.8 g) with mechanical stirring. The chloroacetone was obtained by the chlorination of acetone in the presence of marble [15]. On conclusion of reaction, which lasted approximately 30 minutes, the reaction mixture was let stand overnight. The next day the flask contents were diluted with an equal volume of water, and the excess alcohol was distilled off. The partially oily, partially crystalline 2-acetylbenzofuran that separated here was extracted with ether. The ether extract was dried over anhydrous sodium sulfate, after which the solvent was removed by distillation. The crude product was vacuum-distilled. The yield was as high as 80%. Recrystallization from alcohol gave well-formed, colorless rhombic crystals. M.p. 74°, b.p. 111-112° (3 mm). From the literature: m.p. 76°, b.p. 136° (11 mm) [8].

Found %: C 75.12; H 5.00. $C_{10}H_8O_2$. Calculated %: C 75.00; H 5.00.

b) Preparation of methylbenzofurylcarbinol. Reduction over copper-chromium catalyst. A mixture of 14 g of acetylbenzofuran, dissolved in 250 ml of ethyl alcohol, and 1 g of copper-chromium oxide catalyst [16] was charged into a 0.5 liter autoclave. After purging with hydrogen the pressure was brought up to 120 atm. in the cold; with constant shaking the temperature was raised to 150° and kept there for 18 hours. The pressure in the autoclave after cooling was 98 atm. After cooling the pressure was cautiously released, the solution of the carbinol separated from the catalyst by filtration, the alcohol removed by distillation, and the product repeatedly recrystallized from ligroin. The yield was about 35%, m.p. 40° (from the literature: m.p. 41° [8]). The compound was obtained as colorless prisms with a characteristic odor. Analysis for the amount of hydroxyl group by the Chugaev-Terentyev method gave 9.7% (calculated 10.5%). An attempt to purify the carbinol by vacuum-distillation led to dehydration, a mixture of products was obtained in the receiver, and in addition, about half of the product polymerized in the distillation flask.

2) Reduction with aluminum isopropylate. Pure acetylbenzofuran was dissolved in anhydrous isopropyl alcohol and mixed with an exactly equivalent amount of aluminum isopropylate in such a manner that the reaction mixture contained not more than 10-15% of the original ketone. The alcohol solution of the starting products was slowly heated under reflux to the boil in 2 hours, and then with a good dephlegmator the mixture of acetone and isopropyl alcohol was distilled off in 5-6 hours. After this the practically pure isopropyl alcohol was rapidly removed by distillation. The residue in the flask was decomposed by pouring it in small portions into cooled 5% hydrochloric acid solution. The decomposition products were extracted with benzene, and the extract was dried over sodium sulfate. After removing the solvent by vacuum-distillation the product distilled at 116-118° (3 mm). It is interesting to mention that in this case the dehydration of the carbinol proceeded to a much lesser extent. Recrystallization from ligroin gave white crystals with m.p. 41°. Yield 70%. The amount of hydroxyl groups, determined by the Chugaev-Terentyev method, was 10.1% (theory 10.5%).

Found %: C 73.82; H 6.08. $C_{10}H_{10}O_2$. Calculated %: C 74.07; H 6.17.

In subsequent experiments the carbinol was not isolated, and instead its benzene solution, after some concentration, was used directly for dehydration.

Remarks. In the preparation of aluminum isopropylate, according to our observations, it is better to introduce the carbon tetrachloride into the reaction mixture 1 hour after the start of heating, and not immediately, as is usually done. This leads to a more rapid preparation of the aluminum isopropylate.

c) Preparation of 2-vinylbenzofuran. A benzene solution, containing 20% carbinol and a small amount of phenyl-β-naphthylamine as polymerization inhibitor, was fed into a Pyrex glass dehydration column, filled with granulated aluminum oxide, at a rate of 1-2 drops per second. The pressure in the column was maintained at 5-10 mm, and the temperature at 300 ± 20°.

The benzene solution, containing the reaction products, was washed with water and dried over sodium sulfate, after which the solvent was vacuum-distilled. The residual oily product was also vacuum-distilled. Yield 80%. The 1st fraction distilled at 47-48° (0.5 mm), n_D^{25} 1.6000. The 2nd fraction distilled at 50-52° (0.5 mm), n_D^{25} 1.6022. As shown by analysis, the amount of pure monomer in the 2nd fraction after redistillation was 100%.

It should be mentioned that raising the temperature to 500° during the dehydration process, as is recommended by Elliot [8], leads to strong resinification.

2-Vinylbenzofuran is a colorless oily liquid with characteristic odor.

2-Vinyldibenzofuran

a) Preparation of dibenzofuran. Into a 2-liter metal vessel, fitted with two tube openings, was charged 1 kg of phenol and 1.5 kg of lead oxide. The reaction mixture was heated for 6 hours at the boiling point of phenol under air reflux. After this the vessel contents were poured out to harden. The solidified glassy mass was crushed into pieces and placed in a Wurtz flask, from which the distillation was made. Unreacted phenol distilled from the mixture up to 190°, then the temperature was raised to 250°, and the dibenzofuran distilled in the interval from 250 to 290°. The high-boiling fraction was dissolved in light benzine and treated 2-3 times with an aqueous 10% caustic solution. This treatment removed phenol from the product. After washing with water the benzine solution was dried over calcium chloride, and after evaporating the solvent the residue was vacuum-distilled. The product distilled at 112° (1.5 mm), and after recrystallization from alcohol had m.p. 85-86°. Yield of pure product 15%. The dibenzofuran was obtained as scale crystals with a peculiar odor.

Found %: C 85.35; H 4.81. $C_{12}H_8O$. Calculated %: C 85.71; H 4.76.

b) Preparation of acetyldibenzofuran. Into a 2-liter glass flask, equipped with stirrer, reflux condenser and inlet tube, was introduced 100 g of dibenzofuran, dissolved in 400 ml of benzene. The flask was cooled with ice. To the solution was added 70 g of acetyl chloride and then in small portions in 2-3 hours was added 100 g of anhydrous aluminum chloride. The reaction was continued for 3-4 days at a maximum temperature of 10°. At the end of this time the reaction mixture was decomposed with dilute hydrochloric acid, the benzene solution was washed with water, dried over sodium sulfate, the solvent distilled off, and the obtained product was vacuum-distilled. Yield 50%.

Further purification of the acetyldibenzofuran was achieved by subsequent alternate crystallization from ethyl alcohol and vacuum-distillation, B.p. 167-169° (1 mm), m.p. 81°. The product was obtained as long, soft, silky needles.

Found %: C 80.11; H 5.07. $C_{14}H_{10}O_2$. Calculated %: C 80.00; H 4.76.

c) Preparation of methyldibenzofurylcarbinol. Aluminum isopropylate was used for the reduction, the same as was described for the preparation of the vinylbenzofuran. The yield of the carbinol was as high as 80%. When vacuum-distillation was attempted all of the product polymerized in the distillation flask, for which reason the carbinol was not isolated in pure form, and instead the reduction product after removal of part of the solvent was used directly for dehydration.

d) Preparation of 2-vinyldibenzofuran. A 20% solution of the carbinol was used for the dehydration. The dehydration temperature was 300± 20°. Yield 70%. The vinyl derivative was isolated in the same manner as described above.

Fractionation in vacuo (from $1.6 \cdot 10^{-1}$ to $5.0 \cdot 10^{-1}$ mm Hg) gave 3 fractions: 1st b.p. 127-130°, 4 g; 2nd b.p. 130°, 22 g; 3rd b.p. 132°, 3 g; residue 3 g.

Despite the fact that the 2nd fraction boils within one degree, based on the iodination data, it contains a substantial amount of impurities, for which reason it was subjected to further purification by recrystallization from methyl alcohol at low temperatures. Analysis of the product purified in this manner showed a vinyldibenzofuran content of 99.8%.

2-Vinyldibenzofuran was obtained as tiny white crystals, very low-melting, with m.p. 32°. In the molten state the monomer polymerizes readily.

SUMMARY

1. Essential changes were made in the methods for the synthesis of the vinyl derivatives of furan, benzofuran and dibenzofuran, which made it possible to obtain these compounds in a high state of purity for the first time.

2. The old data were made more accurate and some new physicochemical constants were determined for the vinyl derivatives of furan, benzofuran and dibenzofuran.

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THE HYDROLYSIS OF MALACHITE GREEN DERIVATIVES, CONTAINING METHYL AND SULFO GROUPS

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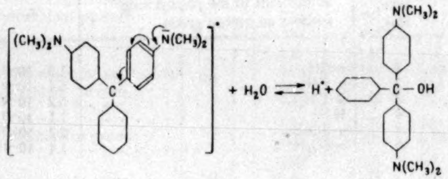
The hydrolysis constants of a whole series of triarylmethane dyes were determined in recent years [1-3]. Here it was found that triarylmethane dyes, containing either electron-donor or electron-acceptor substituents in the ortho-positions to the central carbon atom, show smaller hydrolysis constants than do the unsubstituted dyes [4,5]. However, in the study of Gillois and Rumpf [6] it is indicated that the hydrolysis constant of the dye obtained from bis-(p-dimethylaminophenyl)-o-tolylcarbinol is greater than that of malachite green. This circumstance seemed very strange to us, and for this reason we deemed it expedient to again determine the hydrolysis constant of the dye, containing a methyl group in the ortho-position to the central carbon atom. At the same time it was decided to compare the value of the hydrolysis constant of this dye with the hydrolysis constants of its para- and meta-isomers.

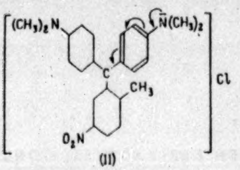
The dyes needed for the study were obtained as the picrates from the corresponding carbinols, the synthesis of which was accomplished through Michler's ketone and the proper organomagnesium compound, and for this reason the position of the methyl groups with respect to the central carbon atom in the studied dyes is without doubt. It should be mentioned that if in running these syntheses the addition of Michler's ketone to the organomagnesium compounds is made not as a solid, but as a solution of the ketone in dimethylaniline, then a considerable increase in the yields of the aminotriphenyl carbinols is obtained.

A quantitative study of the hydrolysis of the dyes, proceeding, for example, for malachite green itself in accord with the equation:

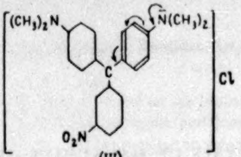


was made by the colorimetric method [3]. The values obtained for the hydrolysis constants are given in Table 1, an examination of which reveals that contrary to the data of Gillois and Rumpf and in accord with our expectations the introduction of a methyl group in the ortho-position to the central carbon atom leads to a substantial reduction in the hydrolysis constant of the dye.

A similar influence of the methyl group can also be shown in other cases. Thus, for example, the hydrolysis constant of the basic turquoise dye (II) is nearly 100 times smaller than the hydrolysis constant of dye (III), obtained from bis-(p-dimethylaminophenyl)-m-nitrophenylcarbinol [7].



(II)



(III)

Since an inverse relationship should exist between the values of the hydrolysis constants of triphenylmethane dyes and the degree of stability shown by the latter to alkaline treatments, the presented data are in full accord with the long known facts, in accord with which methyl groups, found in the ortho-position to the central carbon atom in triphenylmethane dyes, raise the stability of the latter toward alkaline treatments [8]. As regards the influence of methyl groups, found in the meta- and para-positions to the central carbon atom, on the value of the hydrolysis constants of dyes, then this influence is smaller than the influence shown by methyl groups in the ortho-position.

As is known, triphenylmethane dyes, containing sulfo groups in the ortho-position to the central carbon atom, are considerably more stable to the action of alkalies than are the dyes without sulfo groups or with the sulfo groups in the para-position [9]. The data presented in Table 1 permit making a quantitative characterization of the influence shown by the position of the sulfo groups in a series of malachite green derivatives on the stability of the latter to hydrolysis. Here it was found that the hydrolysis constant of the dye, containing the sulfo group in the para-position to the central carbon atom in the phenyl ring without an amino group (p-sulfomalachite green), is only slightly greater than the hydrolysis constant of malachite green itself, while the dye with the sulfo group in the ortho-position (o-sulfomalachite green) shows a hydrolysis constant that is nearly 10,000 times smaller than that of malachite green. As a result, the data obtained in the present study also testify to the fact that substituents, found in the triphenylmethane dyes in the ortho-position to the central carbon atom, independent of whether they are nucleophilic or electrophilic, reduce the hydrolysis of dyes.

TABLE 1

Hydrolysis Constants of Some Dyes of the Malachite Green Group at 17 ± 1°

Expt. Nos.	Substituent in the phenyl ring without an amino group	K_t
1	o-CH$_3$	$1.2 \cdot 10^{-8}$
2	p-CH$_3$	$5.4 \cdot 10^{-8}$
3	m-CH$_3$	$6.2 \cdot 10^{-8}$
4	H [3]	$1.1 \cdot 10^{-7}$
5	p-SO$_3$H	$2.2 \cdot 10^{-7}$
6	o-SO$_3$H	$1.4 \cdot 10^{-11}$

EXPERIMENTAL

Bis-(p-dimethylaminophenyl)-o-tolylcarbinol picrate. To 100 ml of an ether solution of the organomagnesium compound, obtained from 8.4 g (0.05 mole) of o-bromotoluene and 1.2 g (0.05 mole) of magnesium, was gradually added with stirring a solution of 8.9 g (0.033 mole) of Michler's ketone in 100 ml of dimethylaniline. Here a brick-colored precipitate was obtained. After an hour the reaction mass was decomposed with water. The magnesium hydroxide precipitate was filtered, the filtrate made alkaline, and the dimethylaniline steam-distilled. Cooling of the obtained carbinol gave a brick-colored crystalline precipitate. The yield of crude product was 10 g. After recrystallization from benzine, m.p. 155-158°.

To a solution of 3.5 g of the carbinol in 75 ml of alcohol was added 50 ml of a hot alcohol solution containing 2.2 g of picric acid. The resulting picrate was filtered and purified by recrystallization from alcohol; λ_{max} of the dye cation 618 mμ.

Found %: C 62.80; H 5.20; N 12.52. $C_{24}H_{27}N_2 \cdot C_6H_2O_7N_3$. Calculated %: C 63.05; H 5.10; N 12.25.

The picrate of bis-(p-dimethylaminophenyl)-m-tolylcarbinol (λ_{max} of the cation 615 mμ; % N 12.24) and the picrate of bis-(p-dimethylaminophenyl)-p-tolylcarbinol (λ_{max} of the cation 615 mμ; % N 12.60) were prepared in a similar manner.

*Sulfo derivatives of malichite green.** Bis-(p-dimethylaminophenyl)-o-sulfophenylmethane, obtained by the literature method [9], was oxidized in the usual manner with lead dioxide; λ_{max} of the dye 625 mμ.

The dye, containing the sulfo group in the para-position to the central carbon atom, was obtained by the oxidation of bis-(p-dimethylaminophenyl)-p-sulfophenylmethane. λ_{max} of the dye 630 mμ.

Determination of the hydrolysis constants of the dyes. A solution of 10^{-4} mole of the dye in either 100 ml of water or acetone was prepared. To several 25.0 ml buffer solutions, each with a different pH, was added the same amount of the above indicated solution. After equilibrium had been established in a solution its optical density was measured with a Koenig-Martens spectrophotometer at a wave length of 620 mμ. The layer thickness of the studied solution was 20 mm. The obtained data are presented in Table 2. The formula, given earlier [3], was used to calculate the hydrolysis constants.

TABLE 2

Influence of pH on the Color Intensity of the Dye Solutions at 17 ± 1°

Expt. Nos.	Name of compound	Amount of dye (in ml)	pH	E	α	pK_1
1	Bis-(p-dimethylaminophenyl)-o-tolylcarbinol picrate	0.2	4.0	0.693	1.0	—
			7.06	0.604	0.87	7.92
			7.47	0.520	0.75	7.95
			7.92	0.357	0.575	7.94
2	Bis-(p-dimethylaminophenyl)-m-tolylcarbinol picrate	0.1	4.0	0.538	1.0	—
			6.50	0.450	0.83	7.20
			7.06	0.305	0.57	7.18
			7.47	0.204	0.38	7.25
3	Bis-(p-dimethylaminophenyl)-p-tolylcarbinol picrate	0.2	4.0	0.545	1.0	—
			6.50	0.454	0.83	7.29
			7.06	0.332	0.61	7.24
			7.47	0.240	0.44	7.29
4	p-Sulfomalachite green	1.0	4.0	0.771	1.0	—
			6.66	0.383	0.50	6.66
5	o-Sulfomalachite green	1.0	7.00	1.167	1.0	—
			11.45	0.246	0.21	10.87
			11.82	0.115	0.10	10.86

SUMMARY

1. In the reaction of organomagnesium compounds with Michler's ketone a good yield of the aminotriphenylcarbinols is obtained in those cases where Michler's ketone is added, not as a solid, but as a solution in dimethylaniline, to the organomagnesium compounds.

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* E. N. Zinovyev assisted in the preparation of the compound.

2. Derivatives of malachite green, containing methyl groups in the phenyl group devoid of an aminogroup show smaller hydrolysis constants than does malachite green itself; thus the smallest hydrolysis constant is shown by the dye in which the methyl group is found in the ortho-position to the central carbon atom.

3. Triphenylmethane dyes, containing sulfo groups in the ortho-position to the central carbon atom, show considerably smaller hydrolysis constants than do the dyes without sulfo groups or with the sulfo groups in the para-position.

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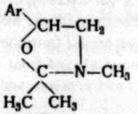
* Original Russian pagination. See C. B. Translation.

ALKAROMATIC AMINO ALCOHOLS

IV. PHARMACOLOGICALLY ACTIVE ARYLTETRAHYDROOXAZOLES

S. I. Sergievskaya, L. E. Sventsitskaya and Yu. I. Syrneva

In one of our previous communications [1], devoted to searches for new sympathomimetic substances, to prove the structure of the amino alcohol chain in α-(m-aminophenyl)-β-methylaminoethanol we condensed this amino alcohol with acetone; the reaction result was the formation of 2,2,3-(trimethyl)-5-(m-aminophenyl)-tetrahydrooxazole (I).



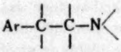
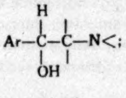
(I)

Ar = m-NH_2—C_6H_4

Pharmacological study (by Yu. I. Syrneva) revealed that this compound has clearly defined sympathomimetic properties and a lower toxicity than the starting (m-aminophenyl)-methylaminoethanol. This information caused us to synthesize several new compounds of similar structure with various aromatic radicals in the hetero ring (Ar = C_6H_5, m-HOC_6H_4, p-HOC_6H_4, p-$NH_2C_6H_4$).

In addition to this we prepared: 2,2-dimethyl-3-ethyl-5-(p-aminophenyl)-tetrahydrooxazole and 2-phenyl-3-methyl-5-(p-aminophenyl)-tetrahydrooxazole.

The synthesis of the enumerated compounds was accomplished by the Knorr method [2], which as yet finds comparatively little use for the preparation of arylated tetrahydrooxazoles. In the majority of cases the hydrochlorides of the corresponding aryl-monoalkylaminoethanols served as the starting substances. The condensation with acetone, and in one case with benzaldehyde, was run in the presence of either potash or ammonia. At times solvents were used.

All of the above indicated aryltetrahydrooxazoles showed sympathomimetic properties in variable degree (Yu. I. Syrneva). • According to contemporary theories the main class of sympathomimetic substances are the alkaromatic amines or amino alcohols of structure:  $\mathrm{Ar{-}\overset{|}{\underset{|}{C}}{-}\overset{|}{\underset{|}{C}}{-}N{<}}$  $\mathrm{Ar{-}\overset{H}{\underset{OH}{C}}{-}\overset{|}{\underset{|}{C}}{-}N{<}}$; the presence in these compounds of an open chain composed of two carbon atoms between the aromatic ring and a secondary or primary amino group is considered to be especially important for the substance to manifest sympathomimetic activity.

The aryltetrahydrooxazoles obtained by us are a different type of sympathomimetic substance, and this can have importance for the development of some new ideas on the subject of the interrelationship between the structure of substances and their pharmacological properties.

• Detailed data on the pharmacological testing of the indicated compounds will be communicated in another place.

Mention of the sympathomimetic properties of some heterocyclic compounds (not considering those in which a nitrogen-containing ring occupies the place of the amino group in the side chain [3]) has been made only in the recently published paper of Thoma and Wick [4], in which reference is made to the pharmacological properties of two aryltetrahydrooxazines: 2-(3,4-dihydroxyphenyl)-tetrahydro-1,4-oxazine and 2-phenyl-3-methyltetrahydro-1,4-oxazine. The authors of this paper emphasize the very great importance of having a secondary amino group in the hetero ring (similar to the compound with an open side chain), and indicate that in aryltetrahydrooxazines with a tertiary amino group in the hetero ring the presence of sympathomimetic properties has not been observed up to now. Contrary to this data, the compounds synthesized by us show sympathomimetic activity, although they contain a tertiary amino group in the hetero ring.

EXPERIMENTAL

2,2,3-Trimethyl-5-phenyltetrahydrooxazole. A mixture of 3 g of α-phenyl-β-methylaminoethanol, 3 g of potash and an excess of acetone was heated on the water bath for 2 hours; on conclusion of heating the mixture was filtered and the acetone was distilled from the filtrate. The residue was vacuum-distilled. The yield of substance with b.p. 125° (10 mm) was 2.15 g (70.3%).

Found %: C 75.19; H 8.83; N 7.24. $C_{12}H_{17}ON$. Calculated %: C 75.35; H 8.94; N 7.32.

2,2,3-Trimethyl-5-(m-hydroxyphenyl)-tetrahydrooxazole. The reaction was run the same as in the previous experiment. For reaction we took 3 g of α-(m-hydroxyphenyl)-β-methylaminoethanol hydrochloride, 1.5 g of potash and 25 ml of acetone. After distilling off the acetone the oily residue was treated with a small amount of anhydrous ether, the ether solution separated from the undissolved portion (starting substance), the ether distilled off, and the residue (2 g) was recrystallized from anhydrous ether to give colorless crystals with m.p. 92-93°. The substance is soluble in ether and acetone, and more difficultly soluble in water.

Found %: C 69.59; H 8.28; N 6.81. $C_{12}H_{17}O_2N$. Calculated %: C 69.53; H 8.26; N 6.76.

2,2,3-Trimethyl-5-(p-hydroxyphenyl)-tetrahydrooxazole. A mixture of 3 g of α-(p-hydroxyphenyl-β-methylaminoethanol hydrochloride and 30 g of anhydrous acetone was heated in the presence of fused potash for 6 hours, after which the acetone solution was filtered, and the acetone distilled in vacuo. The crystalline residue was recrystallized from ether. We obtained 1.6 g (52.5%) of substance with m.p. 144°.

Found %: C 69.26; H 8.12; N 6.64. $C_{12}H_{17}O_2N$. Calculated %: C 69.53; H 8.26; N 6.76.

2,2,3-Trimethyl-5-(p-aminophenyl)-tetrahydrooxazole. The reaction was run and the substance isolated the same as in the preceding experiment. For reaction we took the α-(p-aminophenyl)-β-methylaminophenol hydrochloride obtained from 1.5 g of the free aminoethanol base, 10 ml of acetone, 1.5 g of potash and 10 ml of anhydrous ethyl alcohol. We obtained 1.2 g of colorless crystalline substance; after recrystallization from ether the substance melted at 72.5-74°.

Found %: C 69.70; H 8.78; N 13.70. $C_{12}H_{18}ON_2$. Calculated %: C 69.86; H 8.78; N 13.58.

2,2-Dimethyl-3-ethyl-5-(p-aminophenyl)-tetrahydrooxazole. A suspension of 5 g of α-(p-aminophenyl)-β-ethylaminoethanol dihydrochloride in 20 ml of anhydrous acetone was saturated under cooling with ammonia. After separating, the ammonium chloride and acetone was distilled off. The residue, an oily substance (3 g), crystallized on standing. Recrystallization from anhydrous alcohol gave 1.5 g of colorless crystalline substance with m.p. 86-87°; the substance is readily soluble in alcohol, and insoluble in benzene.

Found %: C 70.91; H 8.80; N 12.77. $C_{13}H_{10}ON_2$. Calculated %: C 70.87; H 9.15; N 12.71.

2-Phenyl-3-methyl-5 (m-hydroxyphenyl)-tetrahydrooxazole. A mixture of 2 g of α-(m-hydroxyphenyl)-β-methylaminoethanol hydrochloride, 1 g of benzaldehyde, a small amount of potash and an excess of anhydrous methyl alcohol was heated for 2 hours. After filtration and removal of the alcohol from the filtrate by distillation the residue was treated with anhydrous ether, the mixture filtered, and the ether removed from the ether solution by distillation. The residual oil was rubbed with ethyl acetate, and the resulting crystals were recrystallized from water. We obtained 1.2 g of substance with m.p. 168-169°.

Found %: N 5.48. $C_{16}H_{17}O_2N$. Calculated %: N 5.48.

The hydrochloride was obtained by dissolving the substance in anhydrous ethyl alcohol and adding an ether solution of hydrogen chloride until acid to Congo.

Colorless crystals, readily soluble in water.

Found %: C 65.64; H 6.28; N 4.65. $C_{16}H_{17}O_2N \cdot HCl$. Calculated %: C 65.86; H 6.28; N 4.65.

SUMMARY

Six compounds of the aryltetrahydrooxazole series were obtained; the obtained substances possess sympathomimetic properties.

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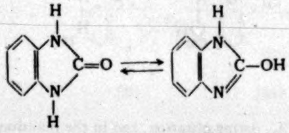
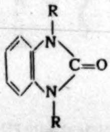
IMIDAZOLE DERIVATIVES

XVII. THE TAUTOMERISM AND DUAL REACTIVITY OF BENZIMIDAZOLONE [1]

L. S. Efros and A. V. Eltsov

Turning to the studies devoted to the chemistry of benzimidazolone it should be mentioned that at first only the o-phenyleneurea (I) structure was assigned to benzimidazolone, in accord with its synthesis from o-phenylenediamine and phosgene [2], or from the o-nitrophenylurethan [3].

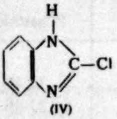

(I) (II)


(III)

A similar opinion was held by Niementowski, who based his decision of the fact that this compound fails to give a color reaction with ferric chloride, and because of its low basicity [4].

The action of benzoyl chloride in aqueous alkaline medium [5], heating with acetic anhydride [6], and the treatment with formaldehyde [7], the same as our studied methylation of benzimidazolone with dimethyl sulfate [8], all lead to the formation of the N,N'-disubstituted derivatives (III).

On the other hand a number of facts are known that could be interpreted [9] as being proof for the existence of a second benzimidazolone tautomer—the 2-hydroxybenzimidazole (II). Thus, the benzimidazole is soluble in alkalies, and when acidified is precipitated again. The treatment of benzimidazolone with phosphorus oxychloride yields the 2-chlorobenzimidazole (IV) [10], the treatment of which with ammonia or with amines gives the 2-amino derivatives (V).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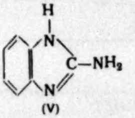
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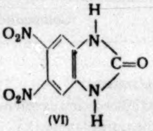
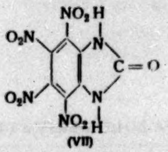
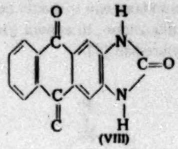

(VI)

All of the benzimidazole derivatives show characteristic behavior when nitrated [11], forming the 5,6-dinitro derivatives, containing nitro-groups in the ortho-position. Benzimidazolone [9] enters into this reaction in exactly the same manner, but with considerably greater ease, giving compound (VI), into which, as we had shown [12], it is possible under more drastic conditions to introduce two more nitro groups and obtain the tetranitro derivative (VII).

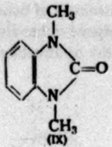


(VII)

Of the benzimidazole derivatives, only the compounds with an active substituent of the Class I type, for example the dimethylamino group, in the 2 position are capable of reacting with phthalic anhydride in the sense of the Friedel-Crafts reaction. Benzimidazolone also reacts with phthalic anhydride, after ring closure forming the 2,3-imidazolonoanthraquinone (VIII) [8].



(VIII)



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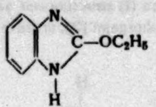


(X)

As a result, in the treatment with $POCl_3$, during nitration, and in the reaction with phthalic anhydride, benzimidazolone behaves as a benzimidazole derivative, containing in the 2 position an active substituent of the Class I type, i.e., 2-hydroxybenzimidazole.

However, in contradiction to such a conclusion are the observations we made[8, 12] that both of the last reactions proceed with equal ease and with the formation of similarly constructed products if, instead of benzimidazolone, we take its 1,3-dimethyl derivative (IX), incapable of tautomerization.

Turning to the state of the tautomeric equilibrium between the (I) and (II) forms of benzimidazolone, it could be thought that this equilibrium is very strongly shifted to the side of the o-phenyleneurea form of benzimidazolone (I).

As was shown in general form by M. I. Kabachnik [13, 14], the state of a tautomeric equilibrium is determined by the acid-base properties of the tautomers. We measured the basicity constants of the 1,3-dimethylbenzimidazolone (IX) and of 2-ethoxybenzimidazole (X), the latter synthesized by the Sandmeyer procedure (15), both being "fixed forms" of the benzimidazolone tautomers (Table).

Compound	$pK_{basicity}$
Benzimidazolone	11.56
1,3-Dimethylbenzimidazolone (IX)	11.46
2-Ethoxybenzimidazole (X)	9.62

An LP-4 lamp potentiometer with glass electrode was used to measure the basicity constants, from the pH of the half-equivalent point at 18°.

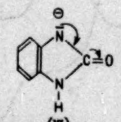
It should be mentioned that the basicity constants of the tautomeric forms of benzimidazolone:

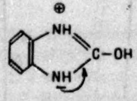
o-phenyleneurea (I) and 2-hydroxybenzimidazole (II), should apparently differ from each other somewhat more than do (IX) and (X) for the following reasons. Compound (IX) should show a somewhat greater basicity than (I), the same as dimethylaniline (K_{basicity} $5.00 \cdot 10^{-10}$) is more basic than aniline (K_{basicity} $3.82 \cdot 10^{-10}$). Compound (X) should be less basic than (II); this follows from a comparison of the basicity of p-aminophenol (K_{basicity} $6.60 \cdot 10^{-9}$ at 15°) and of p-phenetidine (K_{basicity} $2.15 \cdot 10^{-9}$ at 15°).

As can be seen from the data in the Table, 1,3-dimethylbenzimidazolone is actually somewhat more basic than benzimidazolone.

With such a difference in the basicities of (I) and (II) the tautomeric equilibrium should be strongly shifted to the side of the slightly dissociated o-phenyleneurea (I). Apparently, the 2-hydroxybenzimidazole (II) participates in this equilibrium only in exceedingly small amounts.

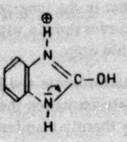
In connection with all of the above we came to the conclusion that the dual reactivity shown by benzimidazolone is explained not by its tautomerism, but by the amphoteric character of this compound and its ability, depending on the conditions, to react either in the undissociated form (I) or in the form of the given below anion (XI) and cation (XII).

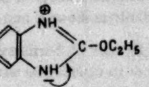

(XI)


(XII)

In this connection we also postulated that in the formation of the cation from benzimidazolone the proton adds not to the nitrogen (since in such case the planar structure of the compound should be disturbed), but to the carbonyl oxygen of (I) with transfer of the positive charge on the nitrogen atom of the imidazole ring, as is shown in the formula of the cation (XII).

This assumption fully explains the above noted similarity in the reactivity in acid medium of benzimidazolone and 1,3-dimethylbenzimidazolone, on the one hand, and of the benzimidazole derivatives, containing an active substituent of the Class I type in the 2 position, on the other, since their cations should have an extremely close structure.





In the present study we decided to verify the validity of these postulations, for which purpose we undertook a study of the ultraviolet absorption spectra of benzimidazolone, 1,3-dimethylbenzimidazolone and 2-ethoxybenzimidazole in media of variable acidity, using methyl alcohol and concentrated sulfuric acid as the solvent.

An SF-4 spectrophotometer of domestic manufacture was used for the measurements, in quartz cuvettes, at solution concentrations ranging from $0.5 \cdot 10^{-3}$ to $4 \cdot 10^{-3}$ g-mole/liter, a layer thickness ranging from 1 to 5 mm, and in the interval from 220 to 350 mμ.

As is known [16-25], benzimidazole derivatives give characteristic absorption curves. Usually in the range 270-280 mμ these curves have two sharp maxima and one minimum, which, depending on the structure of the compound, can be shifted somewhat either to the short-wave or the long-wave region of the spectrum. In neutral methanol (Fig. 1) 2-ethoxybenzimidazole, as was to be expected, gave an absorption curve characteristic for a benzimidazole derivative, whereas the absorption curves of benzimidazolone [16, 19] and of 1,3-dimethylbenzimidazolone do not show a fine structure and give only one absorption maximum at 280 mμ.

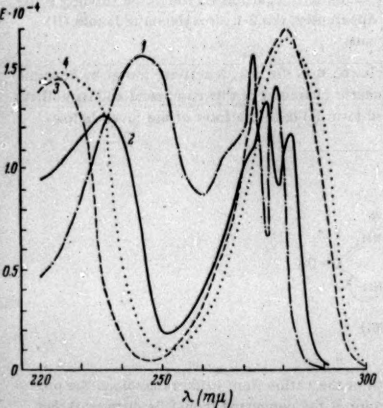


Fig. 1. Ultraviolet absorption spectra in CH_3OH. 1) benzimidazole; 2) 2-ethoxybenzimidazole; 3) benzimidazolone; 4) 1,3-dimethylbenzimidazolone.

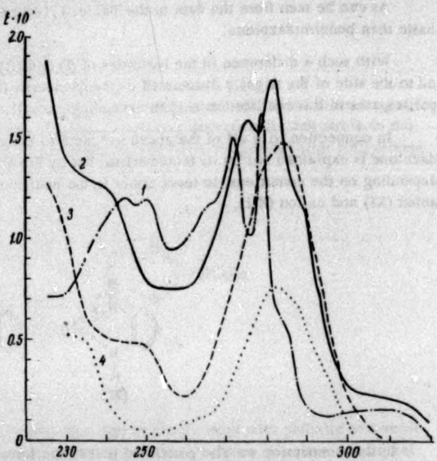


Fig. 2. Ultraviolet absorption spectra in a 0.1N solution of CH_3ONa in CH_3OH. 1) benzimidazole; 2) 2-ethoxybenzimidazole; 3) benzimidazolone; 4) 1,3-dimethylbenzimidazolone.

In passing to an examination of the absorption spectra in 0.1N sodium methylate solution (Fig. 2) it should be mentioned that the character of the absorption curves for the studied compounds, when compared with neutral methanol, fails to show essential change, here for benzimidazolone, as well as for 1,3-dimethylbenzimidazolone, the absorption maximum is shifted somewhat in the long-wave region, while for benzimidazole and 2-ethoxybenzimidazole the extremal values of the curves remain without change. The intensity of absorption for 1,3-dimethylbenzimidazolone shows a noticeable drop.

In acid solutions (Figs. 3-6) in the case of 2-ethoxybenzimidazole and benzimidazole the character of the absorption also does not change, but in connection with salt-formation the extremal values of the curves are shifted in the region of shorter wavelengths, which is very sharply manifested in concentrated sulfuric acid (d 1.84).

Interesting changes in the absorption when the solution pH is lowered are observed for benzimidazolone and 1,3-dimethylbenzimidazolone. Together with a tendency for most of the absorption extremes in the ultraviolet region to shift, the absorption curves show a substantial change in character: in 0.1N HCl (Fig. 3) the maxima of the curves at ~ 280 mμ show some deformation, in 1.2N HCl (Fig. 4) for the case of benzimidazolone in the place of one maximum there appear two quite distinct maxima, and finally, in concentrated H_2SO_4 their adsorption curves become completely analogous in their character to the curves for benzimidazole compounds.

All of the above testifies in favor of the fact that benzimidazolone and 1,3-dimethylbenzimidazolone, forming salts in strongly acid media, add a proton to the oxygen with transfer of the positive charge on the nitrogen atom of the hetero ring and with the formation of cations (XII), containing the hydroxyl group in the

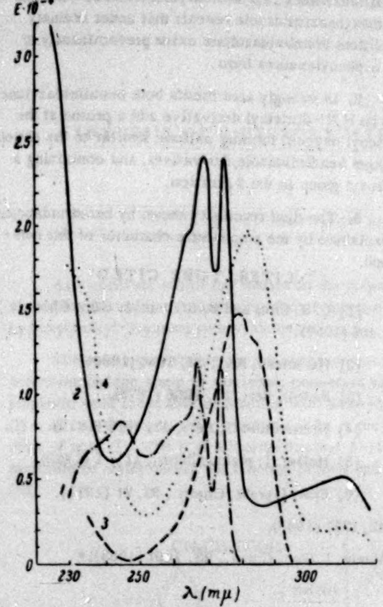


Fig. 3. Ultraviolet absorption spectra in a 0.1N solution of HCl in CH_3OH.
1) benzimidazole; 2) 2-ethoxybenzimidazole; 3) benzimidazolone; 4) 1,3-dimethylbenzimidazolone.

2 position. This, and not tautomerism, explains the similarity in the reactivity of benzimidazole and benzimidazolone derivatives in strongly acid medium.

A complete similarity in the spectral curves of benzimidazolone and 1,3-dimethylbenzimidazolone in neutral methanol and their sharp difference from the absorption spectra of benzimidazole compounds shows that under ordinary conditions the tautomeric equilibrium for benzimidazolone is very strongly shifted to the side of o-phenyleneurea.

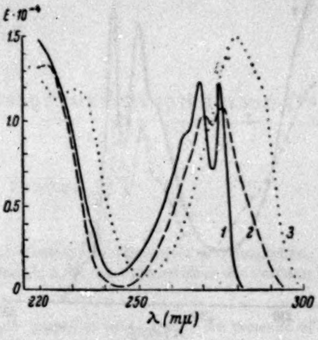


Fig. 4. Ultraviolet absorption spectra in a 1.2N solution of HCl in CH_3OH.
1) 2-ethoxybenzimidazole; 2) benzimidazolone; 3) 1,3-dimethylbenzimidazolone.

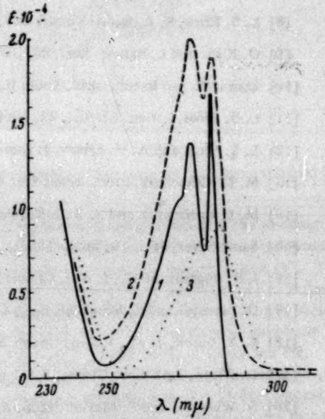


Fig. 5. Ultraviolet absorption spectra in a 9.3N solution of HCl in CH_3OH.
1) 2-ethoxybenzimidazole; 2) benzimidazolone; 3) 1,3-dimethylbenzimidazolone.

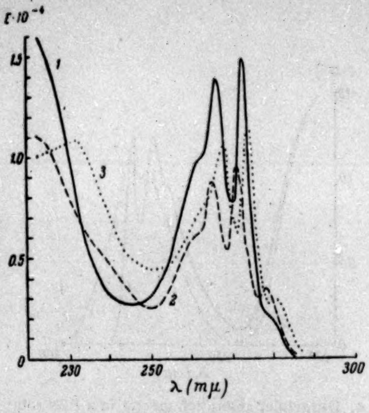


Fig. 6. Ultraviolet absorption spectra in H_2SO_4 (d 1.84).
1) 2-ethoxybenzimidazole; 2) benzimidazolone; 3) 1,3-dimethylbenzimidazolone.

SUMMARY

1. A comparison of the basicity constants and ultraviolet absorption spectra in neutral methanol of benzimidazolone, 1,3-dimethylbenzimidazolone and 2-ethoxybenzimidazole reveals that under ordinary conditions benzimidazolone exists predominantly in the o-phenyleneurea form.

2. In strongly acid media both benzimidazolone and its N,N'-dimethyl derivative add a proton at the carbonyl oxygen, forming cations, similar to the cations of other benzimidazole derivatives, and containing a hydroxyl group in the 2 position.

3. The dual reactivity shown by benzimidazolone is explained by the amphoteric character of this compound.

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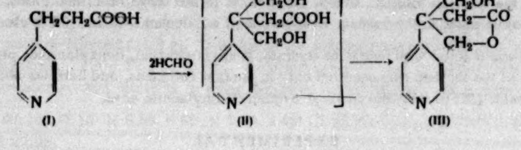
SYNTHESIS OF 3-HYDROXYMETHYL-3-CARBOXYMETHYLQUINUCLIDINE LACTONE

E. E. Mikhlina and M. V. Rubtsov

As a continuation of our studies on the preparation of 2,3-disubstituted derivatives of quinuclidine, and also of the 2- and 3-monosubstituted derivatives of quinuclidine [1, 2, 3], we accomplished the synthesis of 3-hydroxymethyl-3-carboxymethylquinuclidine.

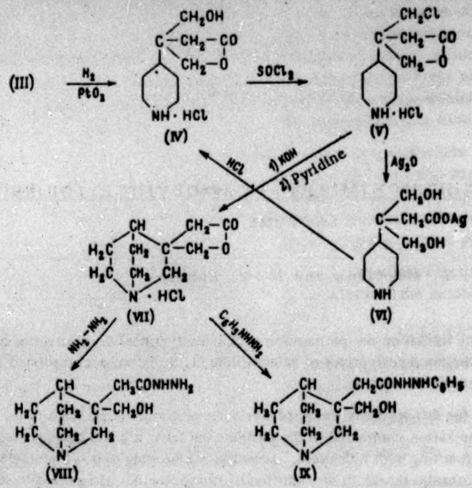
The starting substance for this synthesis was β-(4-pyridyl)-propionic acid. Due to the presence of an active methylene group in the latter, connected to the pyridine nucleus, it could be expected that β-(4-pyridyl)-propionic acid is capable of reacting with aldehydes. Actually, the heating of β-(4-pyridyl)-propionic acid (I) or of its ethyl ester with formalin results in the addition of two molecules of formaldehyde to the β-carbon atom of acid (I). The β,β-dihydroxymethyl-β-(4-pyridyl)-propionic acid (II) that is formed here loses a molecule of water during the reaction process and is converted to β-hydroxymethyl-β-(4-pyridyl)-butyrolactone (III).



The conversion of (III) to 3-hydroxymethyl-3-carboxymethylquinuclidine lactone was accomplished by the scheme shown on the following page.

The hydrochloride of (III) was reduced in either alcohol or hydrochloric acid solution in the presence of platinum oxide (Adams) to β-hydroxymethyl-β-(4-piperidyl)-butyrolactone (IV). The treatment of compound (IV) with thionyl chloride gave the hydrochloride of β-chloromethyl-β-(4-piperidyl)-butyrolactone (V). To convert the latter to 3-hydroxymethyl-3-carboxymethylquinuclidine lactone (VII) it was necessary to isolate the free β-chloromethyl-(4-piperidyl)-butyrolactone base. To accomplish this, hydrochloride (V) was shaken with moist silver oxide. However, here the silver salt of β,β-dihydroxymethyl-β-(4-piperidyl)-propionic acid (VI) was formed, which was due to replacement of the chlorine atom by the hydroxyl group and the opening of the lactone ring in compound (V). Treatment of the silver salt (VI) with hydrochloric acid gave hydrochloride (IV). The ease with which (V) migrates into (VI) indicates the great mobility of the chlorine atom in the chloromethyl group of compound (V). The latter circumstance was also supported by the fact that the vacuum evaporation of a water solution of base (V) at 25-30° gave hydrochloride (IV). The formation of hydrochloride (IV) in the given case was due to replacement of the chlorine atom in base (V) by the hydroxyl group: the hydrogen chloride that was liberated here gave hydrochloride (IV).

β-Chloromethyl-β-(4-piperidyl)-butyrolactone was obtained by treating the hydrochloride of this compound with one equivalent of potassium hydroxide in alcohol solution. The base isolated here was heated with pyridine, which led to the hydrochloride of 3-hydroxymethyl-3-carboxymethylquinuclidine lactone (VII).



Together with the latter compound the hydrochloride of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone (IV) was isolated from the reaction solution, which, the same as in the above described cases, was the result of hydrolyzing the chlorine atom in the vacuum evaporation of an alcohol solution (96 % alcohol) of base (V).

Compound (VII) was reacted with hydrazine hydrate, phenylhydrazine, benzylamine, piperidine and decylamine. Opening of the lactone ring occurred only in the first two cases, and here we obtained the hydrazide (VIII) and phenylhydrazide (IX) of 3-hydroxymethyl-3-quinuclidinylacetic acid.

EXPERIMENTAL

β-Hydroxymethyl-β-(4-pyridyl)-butyrolactone (III). A mixture of 54.4 g of ethyl β-(4-pyridyl)-propionate, 91 g of formalin and 370 ml of water was boiled for 24 hours. The unreacted formaldehyde was steam-distilled, and the reaction solution was vacuum evaporated until crystals appeared. After cooling in ice for two hours the obtained precipitate was suction-filtered, washed with a small amount of alcohol, and dried. Yield 40.7 g (69.5%).

β-Hydroxymethyl-β-(4-pyridyl)-butyrolactone is a white crystalline powder, readily soluble in water, alcohol and acetone, and insoluble in chloroform, ether and benzene. M.p. 132-134° (from anhydrous alcohol).

Found %: C 62.58; H 5.90; N 7.35. $C_{10}H_{11}O_3N$. Calculated %: C 62.23; H 5.70; N 7.25.

To prepare the hydrochloride of β-hydroxymethyl-β-(4-pyridyl)-butyrolactone the above obtained base was dissolved in 100 ml of water with slight heating, the water solution was treated with concentrated hydrochloric acid until acid to Congo, and the obtained precipitate was filtered and washed with alcohol. Yield 46.6 g (94%). Colorless crystals, readily soluble in water, difficultly soluble in alcohol, and insoluble in ether, chloroform and acetone. M.p. 216-217° (from 80% alcohol).

Found %: C 52.17; 52.31; H 5.37; 6.08; Cl 15.45, 15.49. $C_{10}H_{11}O_3N \cdot HCl$. Calculated %: C 52.29; H 5.66 Cl 15.48.

β-Hydroxymethyl-β-(4-piperidyl)-butyrolactone (IV). Variant I. A suspension of 25.5 g of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone hydrochloride in 150 ml of anhydrous alcohol was shaken with hydrogen in the presence of 0.8 g of platinum oxide. After the calculated amount of hydrogen had been absorbed the reaction mass was treated with 100 ml of water, the platinum black was filtered, and the solution was evaporated in vacuo to dryness. We obtained 24.9 g (95%) of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone hydrochloride. Colorless crystals, readily soluble in water, difficultly soluble in alcohol, and insoluble in ether, benzene and in acetone. M.p. 211-213° (decompn.) (alcohol+ether).

Found %: 51.23, 51.06 H 8.00, 7.61 Cl 14.90, 14.84. $C_{10}H_{17}O_3N \cdot HCl$. Calculated %: C 50.95; H 7.64; Cl 15.07.

Variant II. A solution of 16.7 g of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone in 165 ml of 4% hydrochloric acid was shaken with hydrogen at room temperature in the presence of 0.66 g of platinum oxide. After the calculated amount of hydrogen had been absorbed the platinum oxide was filtered, the hydrochloric acid was vacuum distilled, the residue was rubbed with 60 ml of anhydrous alcohol, and the precipitate was filtered and washed with ether. Yield 19.95 g (98.5%). M.p. 211-213° (decompn.).

To isolate the free base 0.6 g of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone hydrochloride was dissolved in 3 ml of water, and the water solution was treated with 3 ml of 50% potash solution and extracted with chloroform. The chloroform solution was dried over potash, the chloroform was distilled off, and the residue was recrystallized from 10 ml of chloroform. Yield 0.4 g (78.8%). White crystalline powder, readily soluble in water and in organic solvents. M.p. 141-143°.

Found %; N 6.88. $C_{10}H_{17}O_3N$. Calculated %: N 7.03.

β-Chloromethyl-β-(4-piperidyl)-butyrolactone (V). A mixture of 15 g of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone hydrochloride, 60 ml of thionyl chloride and 190 ml of anhydrous benzene was heated for 4 hours at 60-65°, and for 4 hours at 70-75°. Then the reaction mixture was cooled, the benzene and excess thionyl chloride decanted from the precipitate, the precipitate washed several times by decantation with benzene, crushed in a mortar, transferred to a filter, and washed on the filter with anhydrous ether. The obtained substance was dissolved under heating in 150 ml of alcohol, and the alcohol solution was filtered and allowed to stand for 24 hours at room temperature. The deposited β-chloromethyl-β-(4-piperidyl)-butyrolactone hydrochloride was suction-filtered (11.3 g). Dilution of the alcohol mother liquor with 50 ml of ether gave another 1.6 g of substance. Yield 12.9 g (79.5%). Colorless crystals, readily soluble in water, difficultly soluble in anhydrous alcohol and insoluble in ether, benzene and chloroform. M.p. 225-227° (decompn.).

Found %: C 47.16, 47.13 H 6.59, 6.62; N 5.49, 5.45; Cl 28.02. $C_{10}H_{16}O_2NCl \cdot HCl$. Calculated %: C 47.24; H 6.68 N 5.51; Cl 27.95.

The alcohol-ether mother liquor yielded 1.3 g of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone hydrochloride.

Reaction of β-chloromethyl-β-(4-piperidyl)-butyrolactone hydrochloride with silver oxide. A mixture of 0.4 g of β-chloromethyl-β-(4-piperidyl)-butyrolactone hydrochloride, 0.8 g of silver oxide and 8 ml of water was shaken for 8 hours. The silver chloride and excess silver oxide were suction-filtered, and the water solution was vacuum evaporated. We obtained 0.42 g of the silver salt of β,β-dihydroxymethyl-β-(4-piperidyl)-propionic acid (VI). White crystalline powder, darkening in the air, and free of chlorine (Beilstein test). The silver salt was dissolved in 20 ml of water, the water solution was treated with concentrated hydrochloric acid until acid to Congo, the deposited silver chloride was filtered, and the hydrochloric acid solution was vacuum evaporated. We isolated 0.3 g of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone hydrochloride. M.p. 211-213°. (decompn.).

3-Hydroxymethyl-3-carboxymethylquinuclidine lactone (VII). A solution of 7.03 g of β-chloromethyl-β-(4-piperidyl)-butyrolactone hydrochloride in 200 ml of alcohol was prepared by heating slightly. To the cooled alcohol solution was added 58.7 ml of 0.5N alcoholic potassium hydroxide solution. The deposited potassium chloride was filtered and the alcohol solution was vacuum evaporated. The residue was treated with 70 ml of anhydrous pyridine, the reaction mass was boiled for 3 hours, cooled, and the precipitate was filtered and washed with anhydrous alcohol. The obtained substance was recrystallized from 110 ml of anhydrous alcohol. The yield of 3-hydroxymethyl-3-carboxymethylquinuclidine lactone hydrochloride was 3.53 g (58.8%). Colorless lustrous needles, readily soluble in water and in hot alcohol, and insoluble in acetone, ether and chloroform. M.p. 310-312° (decompn.).

Found %: N 6.32; Cl 16.04, 15.92. $C_{10}H_{15}O_2N \cdot HCl$. Calculated %: N 6.44; Cl 16.34.

Evaporation of the pyridine soln. and mother liquor after removal of the 3-hydroxymethyl-3-carboxymethylquinuclidine lactone hydrochloride, gave 1.45 g of β-hydroxymethyl-β-(4-piperidyl)-butyrolactone hydrochloride. To obtain the free 3-hydroxymethyl-3-carboxymethylquinuclidine lactone base, 3.65 g of the hydrochloride was treated with 30 ml of 25% potash solution and then it was extracted with chloroform. The chloroform solution was dried over potash, and the chloroform was distilled off. We obtained 2.75 g of substance with m.p. 134-136°. For analysis the obtained substance was vacuum-distilled. B.p. 140° (0.4 mm). Colorless crystals, readily soluble in alcohol, acetone, benzene, chloroform and water, and insoluble in ether and petroleum ether. M.p. 137-139°.

Found %: C 66.36, 66.42; H 8.11, 8.39; N 7.72. $C_{10}H_{15}O_2N$. Calculated %: C 66.18; H 8.28; N 7.71.

The picrate of 3-hydroxymethyl-3-carboxymethylquinuclidine lactone was obtained as a yellow crystalline powder, soluble in acetone and alcohol, and insoluble in ether and water. M.p. 234-236° (from 90% alcohol).

Found %: C 46.91, 46.94; H 4.69, 4.40; N 13.61, 13.41; $C_{10}H_{15}O_2N \cdot C_6H_3O_7N_3$. Calculated %: C 46.83; H 4.38; N 13.66.

3-Hydroxymethyl-3-quinuclidinylacetic acid hydrazide. A mixture of 0.5 g of 3-hydroxymethyl-3-carboxymethylquinuclidine lactone, 1.5 ml of hydrazine hydrate and 5 ml of alcohol was boiled for 10 hours. The alcohol and excess hydrazine hydrate were vacuum-distilled, and the residue was rubbed with ether and filtered. We obtained 0.57 g (98%) of the hydrazide as colorless crystals, readily soluble in alcohol, water and chloroform, and insoluble in ether and benzene. M.p. 145-148° (chloroform+ether).

Found %: N 19.42, 19.56. $C_{10}H_{19}O_2N_3$. Calculated %: N 19.71.

3-Hydroxymethyl-3-quinuclidinylacetic acid phenylhydrazide. A mixture of 0.5 g of 3-hydroxymethyl-3-carboxymethylquinuclidine lactone, 1.5 g of phenylhydrazine and 5 ml of anhydrous alcohol was heated for 10 hours on the boiling water bath. The cooled solution was diluted with 50 ml of absolute ether. The resulting crystals were filtered, washed with ether, and recrystallized from a mixture of alcohol and ether. Yield 0.3 g (37.6%). Colorless crystals, readily soluble in alcohol, and insoluble in water, chloroform and ether. M.p. 151-153° (decompn.).

Found %: C 66.06; H 8.13; N 14.42. $C_{16}H_{23}O_2N_3$. Calculated %: C 66.43; H 7.95; N 14.52.

SUMMARY

The synthesis of 3-hydroxymethyl-3-carboxymethylquinuclidine lactone was accomplished, starting from β-(4-pyridyl)-propionic acid, through β-hydroxymethyl-β-(4-pyridyl)-butyrolactone, β-hydroxymethyl-β-(4-piperidyl)-butyrolactone and β-chloromethyl-β-(4-piperidyl)-butyrolactone.

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ACYLATION OF 6-AMINOANABASINE WITH NICOTINOYL CHLORIDE

N. V. Khromov-Borisov and E. G. Vatkina

Many authors [1-4] have occupied themselves with the problem of acylating the aminonicotines and aminoanabasines. They synthesized the formyl, acetyl and benzoyl derivatives. Thus, for example, by heating aminonicotines with acetic and, correspondingly, benzoic anhydride Goldfarb [1] obtained the acetyl and benzoyl derivatives of aminonicotines. In this case it was the primary amino group, found in the pyridine ring, that underwent acylation, since the tertiary amino group, found in the N-methylpyrrolidine ring, is incapable of acylation reactions. The acylation of amino-N-methylanabasine [3] proceeds in a similar manner, since in it the N-methyl-piperidine ring is also incapable of reacting with acylating agents.

The behavior of 6-aminoanabasine toward acylating agents is somewhat more complex, since in this case the acyl moiety can enter into either the pyridine or the piperdine ring. Consequently, for the monoacyl derivatives it is possible to have isomerism, and as a result of this it becomes necessary to establish the structure of the compounds formed during acylation. However, for the acyl derivatives of 6-aminoanabasine described in the literature (formyl, acetyl and benzoyl) the position of the acyl moiety has not been established. Even in the case of 6-amino-N-methylanabasine, from which individual acylation products were obtained, the indicated investigators did not occupy themselves [3] with a study of the structure of these products.

In the present paper we studied the reaction of 6-aminoanabasine with nicotinoyl chloride. This reaction has not been studied up to now. Considering the two possible positions for the entrance of the nicotinoyl radical into the 6-aminoanabasine molecule, it was first of all necessary to establish whether actually the nicotinoyl radical would enter with greatest ease into the pyridine portion of the molecule, or into the piperidine portion, or whether it would enter with equal ease in both positions. Further, it was also of interest to determine whether the mononicotinoyl derivative is capable of reacting with a second molecule of nicotinoyl chloride to form the dinicotinoyl derivative. In addition, it seemed of interest to trace the influence of introducing nicotinoyl groups into 6-aminoanabasine on its toxicity.

We used our earlier described method [5, 6] to obtain 6-aminoanabasine by the amination with sodium amide of the unseparated technical mixture of anabasine and lupinine. As the nicotination agents we used both nicotinoyl chloride hydrochloride and the free nicotinoyl chloride. We obtained nicotinoyl chloride hydrochloride (m.p. 156°) from nicotinic acid and thionyl chloride [7], and the free nicotinoyl chloride (m.p. 16°) by the reaction of the hydrochloride with pyridine [8].

The reaction of 6-aminoanabasine (1 mole) with nicotinoyl chloride hydrochloride (1 mole) was run in pyridine medium by heating the reaction solution on the water bath. Then aqueous ammonia was added to bind the hydrogen chloride, after which the pyridine was distilled off under reduced pressure.

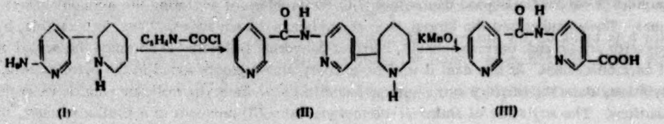
The reaction product after distilling off the pyridine was a glassy mass. It was purified by extraction with water, and recrystallization from water. In the pure state it was a white crystalline powder and had m.p. 150°. The elementary analysis data revealed that this substance is the mononicotinoyl derivative of aminoanabasine.

Then we attempted to obtain the dinicotinoyl derivative of 6-aminoanabasine by running the reaction under more drastic conditions. For this we used an excess of acylating agent, lengthened the reaction time and ran the reaction at a higher temperature, in which connection we used both nicotinoyl chloride hydrochloride and the free nicotinoyl chloride in the reaction. However, in all cases we were able to obtain only the same mononicotinoyl derivative (m.p. 150°).

The obtained nicotinoylaminoanabasine is soluble in alcohol, acetone and chloroform, and also in acetic acid (both glacial and dilute); it is difficultly soluble (0.2%) in cold water; it is practically insoluble in nonpolar organic solvents (ether, aromatic hydrocarbons). The amphoteric character of the obtained nicotinoylaminoanabasine should be mentioned: it is readily soluble in both decinormal acid and decinormal alkali, in which connection it is precipitated in unchanged form when these solutions are neutralized.

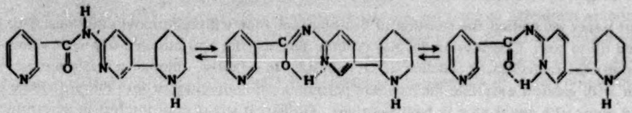
The structure of the obtained nicotinoylaminoanabasine was established by oxidation. The investigated substance was oxidized in water solution with potassium permanganate, and the oxidation product was isolated as the hydrochloride. The elementary analysis gave results that agree with the formula $C_{12}H_{11}O_3N_3Cl_2$.

As a result, in its composition the oxidation product is the hydrochloride of nicotinoylaminonicotinic acid, and consequently, the formation and oxidation of nicotinoylaminoanabasine (II) proceeded by the equation



Consequently, in the nicotination of 6-aminoanabasine the acyl radical is directed to the pyridine, and not to the piperidine ring.

The amphoteric properties of 6-nicotinoylaminoanabasine (II) can be explained by the fact that, together with the groups (piperidine and pyridine rings), imparting the character of a base to the molecule, a labile hydrogen atom is present here, imparting an acidic character to the molecule and making possible either tautomeric transformations or hydrogen bonding.



(For the structure of the acyl derivatives of α-aminopyridine see, for example [10]).

In order to compare the toxicity of 6-aminoanabasine and 6-nicotinoylaminoanabasine we determined the 50 % lethal dose (LD_{50}) of these compounds on white mice; the substances were introduced intraperitoneally as water solutions. For 6-aminoanabasine LD_{50} proved to be equal to 28.5 mg/kg, and for 6-nicotinoylaminoanabasine a dose of 100 mg/kg was still not lethal; the introduction of higher doses of 6-nicotinoylaminoanabasine was not possible due to its low solubility. As a result, the nicotination of 6-aminoanabasine substantially lowered its toxicity.

EXPERIMENTAL

Preparation of 6-nicotinoylaminoanabasine. To a solution of 6.9 g of nicotinoyl chloride hydrochloride in 12 ml of dry pyridine was added 6.86 g of 6-aminoanabasine. The mixture was heated on the boiling water bath for 2 hours under a reflux condenser fitted with a calcium chloride tube. The resulting viscous dark-red liquid was treated with 6.5 ml of concentrated aqueous ammonia solution and the pyridine was distilled off under reduced pressure on the water bath, after which the heating was continued for another 2 hours without disconnecting the vacuum-pump. The obtained glassy mass was dissolved in 500 ml of hot water. A crystalline precipitate separated very slowly from the solution; it was separated and washed with water. Yield: 3.7 g (34%); m.p. 145-150°.

For purification the substance was recrystallized from 370 ml of hot water. We obtained 2.9 g of pure 6-nicotinoylaminoanabasine, representing fine white crystals with m.p. 150°. This substance is insoluble in ether, benzene, toluene, xylene and ammonia; difficultly soluble in cold water (0.2%); soluble in alcohol, chloroform, acetone, glacial and dilute acetic acid, in 0.1N hydrochloric acid and in 0.1N alkali.

Found %: C 67.83, 67.89; H 6.30, 6.21; N 19.68, 19.71. $C_{16}H_{18}ON_4$. Calculated %: C 68.08; H 6.38 N 19.85.

Oxidation of 6-nicotinoylaminoanabasine with potassium permanganate. Two grams of 6-nicotinoylaminoanabasine (m.p. 150°) was dissolved in 400 ml of water. With heating on the water bath and vigorous stirring a 3% potassium permanganate solution was added gradually, after which the mixture was heated for another 2 hours and the manganese dioxide precipitate filtered and washed with hot water. The alkaline filtrate, together with the wash waters, was neutralized with 10% hydrochloric acid (to litmus) and evaporated to a volume of 20-25 ml. The obtained solution was acidified with hydrochloric acid and extracted with ether. The ether extract was dried over anhydrous sodium sulfate and evaporated to dryness. The residue was crushed in a mortar and boiled with anhydrous alcohol. The dried alcohol extract after removal of the alcohol yielded a yellow crystalline substance, which was recrystallized from a mixture of alcohol and ether, and then from alcohol. Yield of the oxidation product (6-nicotinoylaminonicotinic acid) 0.6 g; m.p. 252-253°.

Found %: C 45.32, 45.36; H 3.47, 3.34, N 13.50, 13.43; Cl 23.17, 23.05. $C_{12}H_{11}O_3N_3Cl_2$. Calculated %: C 45.50; H 3.48; N 13.29; Cl 22.46.

To obtain the picrate an alcohol solution of 6-nicotinoylaminonicotinic acid was mixed with an alcohol solution of picric acid. The picrate, recrystallized from alcohol, melted at 215-216°. Its mixture with the picrate of 6-aminonicotinic acid (m.p. 246-248°) [9] melted at 203-207°.

SUMMARY

1. The nicotination of 6-aminoanabasine with nicotinoyl chloride was studied. Both with an equimolar amount of the acylating agent and with an excess, we were able to obtain only the mono-nicotinoylaminoanabasine.

2. The obtained compound is 6-nicotinoylaminoanabasine, since when oxidized it yields 6-nicotinoylaminonicotinic acid.

3. The introduction of the nicotinic acid moiety into the 6-aminoanabasine molecule substantially lowers its toxicity.

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* Original Russian pagination. See C.B.Translation.

For purification the substance was precipitated from [illegible] solution. [illegible] 2.4 g of [illegible] [illegible] [illegible]

Found %: C [illegible] [illegible] N 17.85.

Oxidation of [illegible] [illegible] [illegible]

Found %: C 45.86, 45.86; H [illegible] [illegible] Calculated %: C 45.66; H [illegible]; Cl 22.88.

To obtain the picrate, an alcohol solution of [illegible] was mixed with saturated alcoholic picric acid. [illegible] [illegible] picrate of 8-aminoquinoline [illegible]

SUMMARY

1. The chlorination of [illegible] was studied. [illegible]

2. The obtained [illegible] [illegible] acid.

3. The introduction of [illegible] [illegible] activity.

LITERATURE CITED

[1] Ya. L. Gol'dfarb [illegible]

[2] [illegible]

[3] [illegible]

[4] [illegible]

[5] N. V. Khromov-Borisov and [illegible] J. Gen. Chem. [illegible]

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[7] [illegible] Ber., 44, [illegible]

[8] [illegible] Ber. [illegible]

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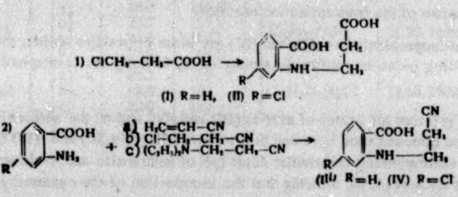
* Original Russian pagination. See C. B. Translation.

β-(2-CARBOXYARYL)-AMINOPROPIONIC ACIDS

A. F. Bekhli

To study the conditions for the formation of β-(2-carboxyaryl)-aminopropionic acids (I and II), capable of serving as starting substances in the synthesis of 1,2,3,4-tetrahydro-4-quinolones, we investigated two directions: 1) the reaction of β-chloropropionic acid with the corresponding anthranilic acids, and 2) the synthesis of the β-(2-carboxyaryl)-aminopropionitriles (III, IV) with their subsequent saponification to acids (I and II). Nitriles (III, IV) were obtained by the reaction of anthranilic acids with a) acrylonitrile, b) β-chloropropionitrile, and c) β-diethylaminopropionitrile.



(I) R=H, (II) R=Cl

(III) R=H, (IV) R=Cl

Of the acids synthesized by us only β-(2-carboxyphenyl)-aminopropionic acid (I) is described in the literature, which was obtained by the oxidation of 1-isatinpropionic acid with hydrogen peroxide [1], and also by the condensation of anthranilic acid with propiolactone [2].

We obtained acids (I) and (II) in 50-70% yield by Reaction 1, i.e. by the reaction of β-chloropropionic acid with the corresponding anthranilic acids under heating in aqueous alkaline medium in the presence of a catalyst (copper acetate). The main problem in obtaining acids (I) and (II) by the second route is a study of the methods for the formation of nitriles (III) and (IV), which up to now have not been described in the literature.

The anthranilic acids can be considered as being compounds close to the aromatic amines with weakened basic properties. We had shown earlier that aromatic amines add to acrylonitrile in the presence of acid catalysts [3]. Attempts to add acrylonitrile to anthranilic acid in water medium, containing 1 equiv. of HCl, gave negative results. If the addition of the acrylonitrile is run in the presence of a weaker acid, for example acetic acid (pH3.1), the formation of β-(2-carboxyphenyl)-aminopropionitrile (III) occurs although in low yield. It was found that the addition to the reaction mixture, containing acetic acid, of 0.6 equiv. of sodium acetate (with respect to the anthranilic acid) raises the yield of nitrile (III) to 44%. An increase in the amount of sodium acetate to 1 equiv. (pH4.6) gives an even greater yield of nitrile (III) (65%). Further study revealed that acrylonitrile adds well to anthranilic and 4-chloroanthranilic acids also in aqueous alkaline medium. Here the best yields of (III) and (IV) (up to 90%) are obtained in a weakly alkaline medium (pH7.3-7.6) in the presence of copper acetate as catalyst.

As a result, the addition of acrylonitrile to anthranilic acid, in contrast to the aromatic amines, can be accomplished in alkaline, as well as in acid medium.

In addition to the direct addition of acrylonitrile to anthranilic acids, nitriles (III) and (IV) can be obtained (by Reaction 2b) by the reaction of anthranilic acids with certain propionitrile derivatives. It was found that nitriles (III) and (IV) are obtained in good yields (88-97%) by heating the anthranilic acids with β-chloropropionitrile in water in the presence of potash and with copper acetate as the catalyst. Apparently, this reaction is not of the alkylation type, but instead its mechanism consists in the decomposition of the β-chloropropionitrile with the cleavage of hydrogen chloride and the subsequent addition of the anthranilic acid to the formed acrylonitrile. This postulation was confirmed experimentally, where it was shown that β-chloropropionitrile under the reaction conditions, i. e. when heated in water solution in the presence of potash, decomposes with the liberation of acrylonitrile and potassium chloride.

Nitriles (III) and (IV) are also formed by the reaction of the corresponding anthranilic acids with β-diethylaminopropionitrile (2c). The process is of the transamination type with the liberation of $NH(C_2H_5)_2$, analogous to our earlier described reaction [4] of aromatic amines with β-diethylaminopropionitrile in the presence of 1 equiv. of acid. In the given case the carboxyl of the taken anthranilic acid forms a salt with the diethylaminopropionitrile, which, the same as other salts of the latter (for example, the hydrochloride), when heated is decomposed to acrylonitrile and the diethylamine salt of the corresponding anthranilic acid. This salt when heated with the formed acrylonitrile yields nitriles (III) and (IV). The yields of nitriles (III) and (IV), obtained by this method, did not exceed 33%.

We found further that the heating of anthranilic acid with acrylonitrile in the presence of diethylamine results in the formation of β-(2-carboxyphenyl)-aminopropionitrile in 52% yield, which serves to support our postulation as to the mechanism of the transamination reaction.

β-(2-Carboxyaryl)-aminopropionitriles (III) and (IV) are white crystalline solids, melting with decomposition. When heated above the melting point they suffer decarboxylation, forming the corresponding β-arylaminopropionitriles.

Determination of the relative pH values of nitriles (III) and (IV) and of the anthranilic acids in aqueous-alcohol solutions of the same concentration revealed that nitriles (III) (pH4.10) and (IV) (pH4.09) show a greater acidity than do the corresponding anthranilic acids (pH of anthranilic and 4-chloroanthranilic acids 4.20). These results agree with the data of [5, 6], showing that the introduction of the cyanoethyl group into the molecule of aliphatic amino acids (aminoacetic acid) raises the acidity of the latter.

Alcohol solutions of nitriles (III) and (IV), when reacted with equimolar amounts of potassium acetate, dissolved in alcohol, form double salts, composed of the mono-K-salt of the β-(2-carboxyaryl)- aminopropionitrile and a molecule of the β-(2-carboxyaryl)-aminopropionitrile. These compounds decompose in hot water to the β-(2-carboxyaryl)-aminopropionitrile, separating from the solution on cooling, and the potassium salt of the nitrile, remaining in solution, from which the nitrile is obtained by the addition of acid.

β-(2-carboxyaryl)-aminopropionitriles are smoothly saponified in alkaline medium, in water, or in aqueous-alcohol solution to the β-(2-carboxyaryl)-aminopropionic acids in 74-94% yield. Attempts to saponify nitrile (III) in acid medium gave negative results, and here the decomposition products were shown to contain β-phenylaminopropionitrile, aniline and CO_2.

The β-(2-carboxyaryl)-aminopropionic acids are crystalline solids, melting with decomposition; when compared with the nitriles and anthranilic acids they show a greater acidity.

Determination of the relative acidity of 0.01M solutions of these acids in 50% alcohol revealed that their pH values (I 3.90, II 3.80) are lower than the pH values of the corresponding nitrile solutions (III 4.1, IV 4.09) and the starting anthranilic acids (pH 4.20).

The β-(2-carboxyaryl)-aminopropionic acids form acid monopotassium salts, difficultly soluble in cold alcohol, when alcohol solutions of one mole of acid and 2 moles of potassium acetate are mixed. Apparently, the salt is formed as the result of the aromatic carboxyl group.

EXPERIMENTAL

The β-(2-carboxyaryl)-aminopropionitriles were obtained by four methods.

a) A mixture of the proper anthranilic acid (1.0 mole), acrylonitrile (1.5-2 moles), potash (0.5 mole) and copper acetate (2.0 moles) in water solution (260 ml) was heated for 7-20 hours at the boil. The β-(2-carboxyaryl)-aminopropionitrile separated from the alkaline solution on acidification.

b) A mixture of the proper anthranilic acid (1 mole), β-chloropropionitrile (1.5 moles), potash (1.35 moles), copper acetate (2.5 g) and water (50-250 ml) was heated for 9-18 hours. The mixture was treated with animal charcoal and filtered. The β-(2-carboxyaryl)-aminopropionitrile separated from the filtrate on acidification.

c) The anthranilic acid (1.0 mole) and diethylaminopropionitrile (1.0 mole) mixture was heated at 160-170° for 2 hours. The mass after cooling was treated with water and acidified.

d) A mixture of the anthranilic acid (1.0 mole), diethylamine (1.0 mole) and acrylonitrile (1.1 moles). was heated at 140-150° for 2.5 hours. The nitrile was isolated by the above described method.

The results of the experiments are given in Table 1.

TABLE 1

Compound		Prep. merhod	Yield of crude product (in %)	Melting point•	Formula	N content (in %)	
						found	calculated
III••	H	a)	88.0	169.5°	$C_{10}H_{10}O_2N_2$	14.98, 14.66	14.73
		b)	97.0	169.5			
		c)	33.6	169.5			
		d)	52.6	169.5			
IV•••	Cl	a)	89.7	189	$C_{10}H_9O_2N_2Cl$	12.80, 12.66	12.47
		b)	88.0	189			
		c)	32.0	189			

Decarboxylation of β-(2-carboxyaryl)-aminopropionitriles.

a) β-(2-Carboxyphenyl) aminopropionitrile (5.0 g) was placed in a small Wurtz flask, the outlet tube of which was connected to a trap containing barium hydroxide solution, and then it was heated in a metal bath at 180°. The nitrile melted with decomposition, evolving carbon dioxide. The residue was treated with alkali solution, and the resulting oil was extracted with benzene. After distilling off the benzene the residue, being β-phenylaminopropionitrile, was vacuum-distilled, b.p. 152° (3 mm), m.p. 49° (from aqueous alcohol); its mixture with the β-phenylaminopropionitrile, obtained by the addition of acrylonitrile to aniline, failed to show a melting point depression.

b) β-(2-Carboxy-5-chlorophenyl)-aminopropionitrile (3.8 g) was heated for 15 minutes at 200°, evolving carbon dioxide. We obtained 0.9 g (30%) of β-(m-chlorophenyl)- aminopropionitrile, m.p. 47.5°.

Double monopotassium salts of β-(2-carboxyaryl)-aminopropionitriles (2-β-cyanoethylaminobenzoic acids). The β-(2-carboxyaryl)-aminopropionitrile (0.025 mole) was dissolved with heating in anhydrous alcohol (80 ml) and added to a solution of potassium acetate (0.025 mole) in anhydrous alcohol (32 ml). The hot solution was filtered. The solution on cooling deposited a white crystalline precipitate of the double salt, composed of one molecule of the potassium salt of the β-(2-carboxyaryl)-aminopropionitrile and one molecule of the free β-(2-carboxyaryl)-aminopropionitrile. A water solution of the salt shows acid to litmus. When heated in water the salt decomposes to the β-(2-carboxyaryl)-aminopropionitrile, separating from the solution on cooling, and the potassium salt of this carboxynitrile, remaining in solution.

The obtained results are presented in Table 2.

• All of the compounds given in the tables melt with decomposition.

•• Compound (III) was recrystallized from aqueous alcohol.

••• Compound (IV) was recrystallized from alcohol.

TABLE 2

R	Yield of double salt• (in %)	Melting point	Formula	Found (%)		Calculated (%)	
				N	K	N	K
H	75	154°—155	$C_{20}H_{19}O_4N_4K$	13.25, 13.37	9.07	13.39	9.35
Cl	72	183 —184	$C_{20}H_{17}O_4N_4Cl_2K$	11.57, 11.94	7.75	11.51	8.02

TABLE 3

Compound	R	Method	Yield of crude acid (in %)	Melting point	Yield of purified acid •• (in %)	Formula	N content (in %)	
							found	calculated
(I)	H	a)	70.3	175° •	—	$C_{10}H_{11}O_4N$	7.13, 6.91	6.69
		b)	—	175	73.9			
(II)	Cl	a)	52.0	190—191	—	$C_{10}H_{10}O_4NCl$	5.83, 5.86	5.75
		b)	95.4	190—191.5	—			

• Literature data: 170° [1], 172.5° [2].

•• Compound (I) was recrystallized from water, and Compound (II) from alcohol.

TABLE 4

R	Yield of salt (in %)	Melting point	Formula	Found (%)		Calculated (%)	
				N	K	N	K
H	97.3	340—345°	$C_{10}H_{10}O_4NK$	5.71, 5.61	16.20	5.62	15.83
Cl	70.0	>300	$C_{10}H_9O_4NClK$	5.23, 5.39	13.55	4.97	13.88

• Recrystallized from anhydrous alcohol.

The β-(2-carboxyaryl)aminopropionic acids were obtained by two methods.

a) A mixture of the proper anthranilic acid (0.5 mole), β-chloropropionic acid (0.75 mole) and potash (1.26 moles) was heated in water solution (200 ml) in the presence of copper acetate (0.5 g) at the boil for 6-9 hours. The reaction mixture was treated with animal charcoal, filtered, and the filtrate acidified with hydrochloric acid.

b) The β-(2-carboxyaryl)-aminopropionitrile (1.0 mole) was heated in an aqueous-alcohol solution (177 ml water+258 ml alcohol) of potassium hydroxide (2.3 moles) at the boil until the evolution of ammonia had ceased (35-40 hours). After distilling off part of the alcohol (112 ml) the residue was treated with animal charcoal, filtered, and the filtrate acidified with hydrochloric acid.

Acid monopotassium salts of β-(2-carboxyaryl)-aminopropionic acids (Table 4).

The β-(2-carboxyaryl)-aminopropionic acid (0.005 mole) was dissolved in anhydrous alcohol and added to a hot alcohol solution of potassium acetate (0.01 mole) in anhydrous alcohol. The solution on cooling gave a crystalline precipitate of the acid monopotassium salt. The precipitate was separated and washed well with anhydrous alcohol. The water solutions of the salts show acid to litmus. When heated in water the salts hydrolyze with the liberation of the β-(2-carboxyaryl)-aminopropionic acids. When heated in acetic anhydride the salts dissolve with foaming and the liberation of carbon dioxide.

Determination of the hydrogen ion concentration in aqueous-alcohol solutions of anthranilic acids and their cyano-and carboxyethyl derivatives. An LP 5 potentiometer with calomel electrode was used for the pH measurements. The data are presented in Table 5.

TABLE 5

pH Values of 0.01M Aqueous Alcohol (50%) Solutions of Anthranilic Acids and Their Derivatives at 20°.

Compounds	pH of the solution	Compounds	pH of the solution
Anthranilic acid	4.20	4-Chloroanthranilic acid	4.20
β-(-2-Carboxyphenyl)-aminopropionitrile	4.10	β-(2-Carboxy-5-chlorophenyl)-aminopropionitrile	4.09
β-(2-Carboxyphenyl)-aminopropionic acid	3.90	β-(2-Carboxy-5-chlorophenyl)-aminopropionic acid	3.80

SUMMARY

1. Two methods were developed for the synthesis of β-(2-carboxyaryl)-aminopropionic acids: 1) the reaction of β-chloropropionic acid with anthranilic acids, and 2) the saponification of β-(2-carboxyaryl)-aminopropionitriles.

2. Three methods were described for the preparation of β-(2-carboxyaryl)-aminopropionitriles by the reaction of anthranilic acids with 1) acrylonitrile, 2) β-chloropropionitrile, and 3) β-diethylaminopropionitrile. It was shown that the last two reactions proceed with decomposition of the taken nitriles and the liberation of acrylonitrile, which then adds to the corresponding anthranilic acid.

3. It was shown that the reaction of the β-(2-carboxyaryl)-aminopropionitriles with potassium acetate in alcohol solution yields difficultly soluble double salts, composed of 1 mole of the potassium salt of the β-(2-carboxyaryl)-aminopropionitrile and 1 mole of the free β-(2-carboxyaryl)-aminopropionitrile; under the same conditions the dicarboxylic acids, corresponding to the indicated nitriles, also form acid monopotassium salts that are difficultly soluble in alcohol.

4. It was established that the introduction of either the cyanoethyl or the carboxyethyl group on the amino group of anthranilic acids raises the acidity of the latter.

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DETERMINATION OF THE EUTECTIC FUSION OF THREE- AND FOUR-COMPONENT ORGANIC SYSTEMS

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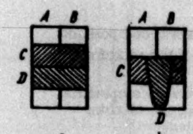
At the present time it is generally accepted [1-4] that there is eutectic fusion of binary systems at the point of contact of two phases. S. V. Avakyan and N. F. Lashko [1, 5] showed that the fusion of eutectic alloys also occurs in the simultaneous contact of three and four phases, forming ternary and quaternary eutectics. The authors, operating only with metals, made the contact by bringing a polished plate of the binary eutectic in contact with a polished plate of the third component or of a second binary eutectic. After heating these plates at temperatures, exceeding the melting points of the ternary and quaternary eutectics by 5-10°, it was possible to observe all of the components of the eutectic phase in the structure of the molten substance.

The use of such a method to study the eutectic fusion of organic mixtures is not feasible, due to the inability of preparing the polished specimens. Tables could be used instead of polished specimens; however, most organic substances cannot be molded without using such binders as talc, lactose, alcohol, water, etc. In addition, it is difficult to observe the structures characeristic for the eutectic on the surfaces of tablets. Consequently, to determine the eutectic fusion point of three- and four-component organic systems we used the same method that we had used earlier to determine the eutectic fusion of binary organic systems [6-8].

Essentially the method is to place a crystal of the third component on the eutectic binary mixture, or of a crystal of the second binary eutectic or of the fourth component on either the eutectic binary or ternary mixture, and look for the appearance of a liquid phase under the microscope (stereoscopic models MBS-1 and MBS-2). Also, it is possible to look for the fusion of a granule, composing the mixture of a three-or four-component system.



a b

Possible combinations of component distribution in a four-component system.

The simultaneous contact of three components is without doubt accomplished very easily; to realize simultaneous contact in a four-component system is, however, less possible. Combinations that it is possible to depict here are those where on two contacting components A and B are distributed two other components C and D, having a plane of contact (Fig. a), or where component D of irregular form lies in one portion on component C, and in another portion on contiguous substances A and B (Fig. b). Judging by our experimental data, the number of these possibilities is still so great that it is sufficient to accomplish simultaneous contact between four components and to look for the fusion of the quaternary eutectic.

We give in Table 1 the data on the melting points of three-component organic systems, obtained by us by the method of contact fusion, and by Hrynakowski and Adamanis [9] by the method of thermal analysis. A comparison of these data reveals satisfactory agreement in eight of the eleven cases. As regards Systems 8 and 9, it was here impossible to expect agreement, since in the fusion of these substances the antipyrine reacts with the salicylic and benzoic acids, forming known compounds – salipyrine [10] and antipyrine benzoic acid [11]. In their indicated composition of the eutectic (System 8, Table 1) there enters 67.5% of antipyrine, which with excess assures complete binding of both acids; consequently, the eutectic observed by the indicated authors apparently corresponds to the composition salipyrine-antipyrine-antipyrine benzoic acid. In System 9 the antipyrine does not suffice to bind all of the salicylic acid; in addition, the latter can also react with urea [12], so that after fusion the system undoubtedly becomes multicomponent. In our observations the substances

TABLE 1

Comparison of the Melting Points of Ternary Eutectics, Determined by the Method of Contact Fusion

System No.	Components	Melting point	Composition of the eutectic (in wt. %)	Melting point of the eutectic		Composition of the studied three-component system
				from the data of[9]	our data	
1	Antipyrine . . .	111.5°	41.0	45.0°	44.0°	Mixture of haphazard composition
	Phenacetin . . .	134—136	26.0			
	Acetanilide . . .	114.0	33.0			
2	Antipyrine . . .	111.5	40.0	29.0	27.8	Mixture of haphazard composition
	Phenacetin . . .	134—136	7.5			
	Urethane	49—50	52.5			
3	Antipyrine . . .	111.5	13.5	32.0	31.4	Mixture of haphazard composition
	Phenacetin . . .	134—136	4.0			
	Salol	40—41	82.5			
					29.8	Eutectic composition of the mixture
4	Antipyrine . . .	111.5	16.0	31.0	29.3	Eutectic composition of the mixture
	Phenacetin . . .	134—136	1.5			
	Menthol	43.0	82.5			
5	Antipyrine . . .	134—136	15.0	30.0	30.0	Mixture of haphazard composition
	Acetanilide . . .	114.0	42.5			
	Resorcinol	111.0	42.5			
6	Antipyrine . . .	111.5	47.5	61.0	62.0	Eutectic composition of the mixture
	Salipyrine	91.0	30.0			
	Urea	133.0	22.5			
7	Antipyrine . . .	111.5	34.0	50.0	48.3	Eutectic composition of the mixture
	Resorcinol	111.0	61.0			
	Urea	133.0	5.0			
8	Antipyrine . . .	111.5	67.5	59.0	49.5	Eutectic composition of the mixture
	Salicylic acid	155	7.0			
	Benzoic acid . .	121.5	25.5			
9	Antipyrine . . .	111.5	40.0	42.0	64.5	Eutectic composition of the mixture
	Urea	133.0	21.0			
	Salicylic acid .	155.0	39.0			
10	Antipyrine . . .	111.5	59.0	69.0	68.1	Eutectic composition of the mixture
	Urea	133.0	6.0			
	Phenacetin . . .	134—136	35.0			
11	Acetanilide . . .	114—115	65.0	67.0	84.1	Eutectic composition of the mixture
	Urea	133.0	5.0			
	Phenacetin . . .	134—136	30.0			

do not fuse and they do not heat up above the melting point of the ternary eutectic, as a result of which the eutectic melting points observed by us relate to systems of a different composition. In all probability this same circumstance is also the explanation for the divergence in the melting points of System 11. From the data in Table 1 it can also be seen that the determination of eutectic fusion can be run, not only on systems showing a eutectic composition, but also on a granule of a mixture of haphazard composition.

After we had become convinced that the contact fusion method was suitable for determining the eutectic melting points of three-component systems, we established the eutectic melting points for 23 three-component organic systems, the major portion of which represent medicinal drugs. Consequently, the method can find practical use for internal druggist control with the purpose of identifying three-component drug powders and tablets (Table 2).

TABLE 2

Determination of the Eutectic Melting Points of Three-Component Organic Systems

System No.	Components and their designation	Melting point of components	Melting point of the eutectic			
			A + *B*	*A* + *C*	*B* + *C*	*A* + *B* + *C*
1	*A* — phenacetin *B* — antipyrine *C* — caffeine	134—136.0° 111.5 234.0	75.5°	127.0°	105.6°	72.9°
2	*A* — aspirin *B* — acetanilide *C* — caffeine	133—136 114 234.0	82.3	102.6	106.2	77.9
3	*A* — antipyrine *B* — aspirin *C* — caffeine	111.5 133—136 234	55.7	105.6	102.6	53.5
4	*A* — salol *B* — aspirin *C* — caffeine	41.0 133—136.0 234.0	39.3	38.3	102.6	35.0
5	*A* — salol *B* — aspirin *C* — caffeine sodium benzoate	41.0 133—136 —	39.3	40.3	80.6	34.5
6	*A* — pyramidone *B* — phenacetin *C* — caffeine	108 134—136.0 234	81.4	104.0	127.1	80.1
7	*A* — pyramidone *B* — antipyrine *C* — caffeine sodium benzoate	108.0 111.5 —	78.6	104.6	106.6	78.5
8	*A* — pyramidone *B* — caffeine *C* — caffeine sodium benzoate	108.0 155.0 —	92.8	104.6	152.5	93.0
9	*A* — pyramidone *B* — phenacetin *C* — antipyrine	108.0 134—136.0 111.5	81.4	78.6	75.5	61.1
10	*A* — pyramidone *B* — phenacetin *C* — aspirin	108.0 134.0—136.0 133.0—136.0	81.4	50.4	98.8	44.6
11	*A* — pyramidone *B* — Phenacetin *C* — acetanilide	108.0 134.0—136.0 114.0	81.4	60.4	90.4	52.9
12	*A* — phenacetin *B* — aspirin *C* — acetanilide	134—136.0 133—136.0 114.0	98.8	90.4	82.3	70.0
13	*A* — pyramidone *B* — aspirin *C* — acetanilide	108.0 133—136.0 114.0	50.4	60.4	82.3	40.9
14	*A* — antipyrine *B* — codeine *C* — acetanilide	111.5 155.0 114.0	91.8	47.9	95.1	46.4
15	*A* — antipyrine *B* — acetanilide *C* — caffeine	111.5 114.0 234.0	47.9	105.0	106.2	46.7
16	*A* — antipyrine *B* — codeine *C* — caffeine	111.5 155.0 234.0	91.8	106.0	140.8	88.6

TABLE 2 (Continued)

System No.	Components and their designation	Melting point of the components	Melting point of the eutectic			
			A + B	A + C	B + C	A + B + C
17	A — acetanilide . . .	114.0°	95.1	106.2	140.8	92.5
	B — codeine	155.0				
	C — caffeine	234.0				
18	A — pyramidone . . .	108.0	104.0	78.6	106.0	78.6
	B — caffeine	234.0				
	C — antipyrine	111.5				
19	A — aspirin	133—136.0	82.3	84.4	95.1	71.7
	B — acetanilide . . .	114.0				
	C — codeine	155.0				
20	A — phenacetin . . .	134—136.0	90.4	118.3	95.1	82.1
	B — acetanilide . . .	114.0				
	C — codeine	155.0				
21	A — pyramidone . . .	108.0	81.4	88.6	123.9	72.0
	B — phenacetin . . .	134—136.0				
	C — veronal.	190.0				
22	A — phenacetin . . .	134—136.0	123.9	127.1	> 146	116.3
	B — veronal.	190.0				
	C — caffeine	234.0				
23	A — pyramidone . . .	108.0	88.6	104.0	> 146	84.6
	B — veronal.	190.0				
	C — caffeine	234.0				

Not having at our disposal literature data on the eutectic fusion of these systems, to verify the validity of the obtained results we established the eutectic melting points of all of the binary systems, formed from the substances composing the three-component system. Actually, the ternary eutectics proved to have lower melting points than the lowest-melting eutectic of the corresponding binary systems. The reproducibility of parallel determinations was fully satisfactory, and the time required for a determination was 20-30 minutes.

A total of five four-component organic systems was studied. To verify the reliability of the obtained results we determined the eutectic melting points of all of the binary and ternary systems, representing the coupling elements of the four-component system. Consequently, it became necessary to establish for each four-component system the eutectic melting points of six binary and four three-component systems, and to compare them with the eutectic melting points of the four-component systems, the latter in all five cases proving to be lower (Table 3). The probability of simultaneous contact of five and more components is so small that, as far as we can see, the possibility of using the contact fusion method to determine the eutectic melting point of such multicomponent systems should not even be considered.

TABLE 3

System No.	Components and their designation	Melting point	Eutectic melting point of the system										
			A + B	A + C	A + D	B + C	B + D	C + D	A + B + C	A + B + D	B + C + D	A + C + D	A + B + + C + D
1	A — pyramidone B — phenacetin C — caffeine D — antipyrine	108.0° 134—136.0 234.0 111.5	81.4°	104.0°	78.6°	127.1°	75.5°	106.0°	80.1°	61.1°	73.0°	78.6°	59.2°
2	A — pyramidone B — phenacetin C — aspirin D — acetanilide	108.0 134—136.0 133—136.0 114.0	81.4	50.4	60.4	98.8	90.4	82.3	44.6	52.9	71.0	40.9	34.3
3	A — antipyrine B — codeine C — acetanilide D — caffeine	111.5 155.0 114.0 234.0	91.8	47.8	106.0	95.1	140.8	106.2	46.4	88.6	92.5	46.7	43.6
4	A — phenacetin B — aspirin C — acetanilide D — codeine	134—136.0 133—136.0 114.0 155.0	98.8	90.4	118.3	82.3	84.4	95.1	71.0	89.3*	71.7	82.1	65.4
5	A — pyramidone B — phenacetin C — veronal D — caffeine	108.0 134—136.0 190.0 234.0	81.4	88.6	104.0	123.9	127.1	> 146	72.0	80.1	116.3	84.6	66.4

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* The melting point of the ternary eutectic(A + B + C) was somewhat higher than the melting point of the binary eutectic (B + D): the reason for this was not established.

SUMMARY

It was shown that the contact fusion method can be used to determine the eutectic melting points of three- and four-component organic systems. Based on the rapidity of determination and ease of execution the proposed method is the simplest of all of the existing methods for determining the melting points of eutectics. The method can find practical application for the identification of drug powders, containing three and four components.

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THE CATALYTIC TRANSFORMATIONS OF ALKYLDICHLOROSILANES AND DIALKYLCHLOROSILANES IN THE PRESENCE OF ALUMINUM CHLORIDE

B. N. Dolgov, M. G. Voronkov and S. N. Borisov

A quite inadequate study has been made of the thermal and catalytic transformations of the alkylchlorosilanes of type $R_nSiH_mCl_{4-(n+m)}$ (R = alkyl or aryl; m = 1,2; m+n = 2,3). Sauer and Hadsell [1], by heating methyldichlorosilane in an autoclave at 325° for a day in the presence of anhydrous $AlCl_3$ (2% by weight), obtained a complex mixture of gaseous and liquid reaction products, containing SiH_4, H_3SiCl, H_2SiCl_2, $HSiCl_3$, CH_3SiCl_3 and $(CH_3)_2SiCl_2$. Clark [2] obtained phenyldichlorosilane and phenylchlorosilane by heating diphenylchlorosilane with $AlCl_3$, at 150-200° and a pressure not exceeding 60 mm. Rust [3] established that at 450-500° there occurs dehydrocondensation of phenyldichlorosilane.

$$2C_6H_5SiHCl_2 \longrightarrow C_6H_5SiCl_2C_6H_4SiHCl_2 + H_2.$$

A mixture of phenyldichlorosilane and methydichlorosilane (1:1) under these conditions yields essentially $CH_3SiCl_2C_6H_4SiHCl_2$. Speier and Zimmerman [4] recently showed that in the presence of aluminum chloride phenylchlorosilane disproportionates in accord with the scheme

$$5C_6H_5SiH_2Cl \longrightarrow (C_6H_5)_2SiCl_2 + (C_6H_5)_3SiCl + SiH_4 + 2H_3SiCl.$$

In the present study we investigated the transformations of ethyldichlorosilane, butyldichlorosilane and diethylchlorosilane in the presence of anhydrous $AlCl_3$ and $FeCl_3$. We found that in the presence of aluminum chloride the alkyldichlorosilanes and dialkylchlorosilanes disproportionate, entering into the reaction of conjugated hydrogenation-halogenation, which can be depicted by the general scheme

$$R_nSiHCl_{3-n} + R_nSiHCl_{3-n} \longrightarrow R_nSiCl_{4-n} + R_nSiH_2Cl_{2-n},$$

where n = 1, 2. In the case of $RSiHCl_2$ (n = 1) this transformation can be more profound

$$3RSiHCl_2 \longrightarrow 2RSiCl_3 + RSiH_3.$$

Thus, even the slow distillation of ethyldichlorosilane over anhydrous aluminum chloride (Fig. 1) results in disproportionation by the scheme

$$2C_2H_5SiHCl_2 \longrightarrow C_2H_5SiH_2Cl + C_2H_5SiCl_3. \qquad (1)$$

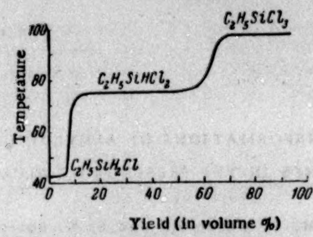


Fig. 1. Curve for the distillation of the disproportionation products obtained in the distillation of $C_2H_5SiHCl_2$ over $AlCl_3$.

The yield of the disproportionation products constitutes a total of 76-80% (based on reacted ethyldichlorosilane and is practically independent of the amount of taken $AlCl_3$, although the amount of the individual disproportionation products in the distillate shows essential dependence on this. In the presence of 15-20% $AlCl_3$ the ethyldichlorosilane is converted to the extent of 37-38% into ethylchlorosilane and to the extent of 39-43% into ethyltrichlorosilane. At 40% and more of $AlCl_3$ the conversion of ethyldichlorosilane into ethyltrichlorosilane exceeds 50%, while the conversion into ethylchlorosilane drops to 26-17%. In the presence of less than 5-6% $AlCl_3$ the disproportionation of $C_2H_5SiHCl_2$ hardly goes. The optimum yield of ethylchlorosilane, up to now unknown, is 76%, based on Equation (1). As a result, we found a simple and convenient method for the synthesis of a nearly unstudied class of organosilicon compounds – the alkylchlorosilanes ($RSiH_2Cl$). The dependence of the yield of the transformation products of $C_2H_5SiHCl_2$ on the amount of $AlCl_3$, shown in Table 1 and Fig. 2, can apparently be explained by a secondary reaction, proceeding in the presence of more than 40% $AlCl_3$.

$$C_2H_5SiHCl_2 + C_2H_5SiH_2Cl \longrightarrow C_2H_5SiCl_3 + C_2H_5SiH_3. \qquad (2)$$

By combining Equations (1) and (2) it becomes possible to depict the reaction for the disproportionation of ethyldichlorosilane in the more general form

$$5C_2H_5SiHCl_2 \longrightarrow 3C_2H_5SiCl_3 + C_2H_5SiH_2Cl + C_2H_5SiH_3. \qquad (3)$$

This equation well explains the fact that in the reaction of ethyldichlorosilane with more than 40 mole % of $AlCl_3$ the yield of ethyltrichlorosilane exceeds the yield theoretically possible on the basis of Equation (1). Based on Equation (3), the yield of ethyltrichlorosilane from ethyldichlorosilane reaches 94%.

When boiled for a long time with $AlCl_3$, ethyldichlorosilane shows practically complete disproportionation in accord with the scheme

$$3C_2H_5SiHCl_2 \longrightarrow 2C_2H_5SiCl_3 + C_2H_5SiH_3. \qquad (4)$$

With a given amount of $AlCl_3$ (50 mole %) the degree of ethyldichlorosilane conversion increases with increase in the reaction time, which is evidently facilitated by the removal of the formed ethylsilane (b. p. -14° from the reaction zone (Table 2 and Fig. 3).

TABLE 1

Yield of Disproportionation Products in the Distillation of Ethyldichlorosilane Over $AlCl_3$

Amount of $AlCl_3$ (in mole % to $C_2H_5SiHCl_2$)	Conversion of $C_2H_5SiHCl_2$ (in %)	Yield of disproportionation products (in mole % on reacted $C_2H_5SiHCl_2$)	
		$C_2H_5SiCl_3$	$C_2H_5SiH_2Cl$
2.8	0.0	0.0	0.0
4.8	0.0	0.0	0.0
8.3	7.5	21.8	13.3
13.5	21.4	39.1	36.8
21.3	29.7	42.5	37.8
32.2	(50.4)	47.0	25.7
40.0	43.5	49.3	28.3
50.7	37.3	52.1	26.4
60.5	42.3	(45.3)	(32.4)
75.0	45.6	(44.1)	23.7
98.8	44.2	56.3	21.2
147.6	47.9	56.5	17.0

TABLE 2

Yield of Disproportionation Products in the Boiling of $C_2H_5SiHCl_2$ With $AlCl_3$

Amount of $AlCl_3$ (in mole % to $C_2H_5SiHCl_2$)	Reaction time (in hours)	Conversion of $C_2H_5SiHCl_2$ (in %)	Yield of disproportionation products (in mole % on reacted $C_2H_5SiHCl_2$)	
			$C_2H_5SiCl_3$	$C_2H_5SiH_2Cl$
50.7	2	37.3	52.1	26.4
49.3	4	44.9	55.6	Trace
49.1	6	49.2	51.5	1.0
50.2	9.5	54.8	52.1	0.4

More complex transformations take place when ethyldichlorosilane is heated with $AlCl_3$ (5-10 mole %) in an autoclave at 230° for 8-40 hours. The reaction develops pressures up to 56 atm. (24 atm. at room temperature) and both gaseous and liquid products are formed. Distillation of the liquid reaction products revealed that they consist of ethylchlorosilane, unreacted ethyldichlorosilane, ethyltrichlorosilane and diethyldichlorosilane (Table 3 and Fig. 4). The gaseous reaction products ignite spontaneously in the air even at -80°, explode when collected over water, and decolorize a solution of iodine in CCl_4, at the same time reducing the CCl_4, to chloroform.

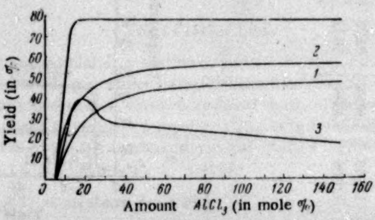


Fig. 2. Dependence of the yields of the $C_2H_5SiHCl_2$ disproportionation products on the amount of $AlCl_3$.
1) conversion of ethyldichlorosilane, 2) yield of ethyltrichlorosilane, 3) yield of ethylchlorosilane, 4) total yield of $C_2H_5SiCl_3$ and $C_2H_5SiH_2Cl$.

Due to the great danger of their explosion the gaseous products were not studied closer, but it can be assumed that silane or its homologs enter into their composition. In addition, the presence of hydrogen was established. The formation of silane can be explained by the following scheme

$$2C_2H_5SiHCl_2 \longrightarrow C_2H_5SiCl_3 + C_2H_5SiH_2Cl;$$
$$2C_2H_5SiH_2Cl \longrightarrow (C_2H_5)_2SiCl_2 + SiH_4. \qquad (5)$$

TABLE 3

Properties of Obtained Ethylchlorosilanes

Compounds	Melting point	Pressure (in mm)	d_4^{20}	n_D^{20}	MR_D		Elementary analysis (in %)					
							Cl		Si		H	Si — H
					found	calculated according to [6]	found	calculated	found	calculated	found	calculated
Ethylchlorosilane . .	43.0°	751	0.9013	1.3975	25.31	25.72	38.9, 39.0	37.47	—	—	1.63, 1.64	2.13
Ethyldichlorosilane .	75.2	763.5	1.0892	1.4162	29.75	29.78	54.9, 54.9	54.95	—	—	—	—
Ethyltrichlorosilane .	98.0	753.5	1.2393	1.4253	33.76	33.78	65.0, 65.2	65.05	17.27	17.17	—	—
Diethyldichlorosilane	129.1	762	1.0705	1.4328	38.13	38.78	45.8, 46.0	45.13	17.93	17.87	—	—

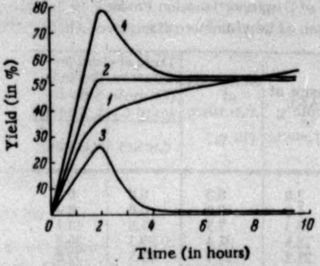


Fig. 3. Dependence of the yield of disproportionation products of the reaction time of $C_2H_5SiHCl_2$ with $AlCl_3$.
1) conversion of ethyldichlorosilane, 2) yield of ethyltrichlorosilane, 3) yield of ethylchlorosilane, 4) total yield of $C_2H_5SiCl_3 + C_2H_5SiH_2Cl$.

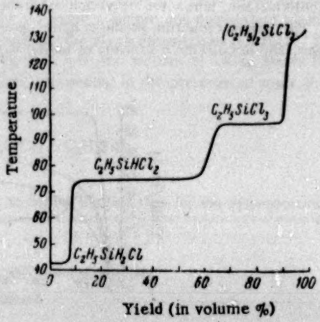


Fig. 4. Distillation curve for the reaction products of ethyldichlorosilane with $AlCl_3$ at 230° and 56 atm.

In contrast to the reaction with $AlCl_3$, ethyldichlorosilane fails to suffer any changes with 50 mole % anhydrous $FeCl_3$, either when distilled or when boiled for 8 hours. The heating of ethyldichlorosilane with $FeCl_3$ (4 mole %) in an autoclave at 240° for 24 hours yields only traces of ethyltrichlorosilane, and nearly all of the ethyldichlorosilane remains unchanged.

The distillation of butyldichlorosilane with 50 mole % $AlCl_3$ yields traces of butylsilane and small amounts of butylchlorosilane and butyltrichlorosilane; however, the major portion of the starting butyldichlorosilane remains unchanged. As a result, butyldichlorosilane disproportionates in the same manner as ethyldichlorosilane, mainly by the scheme

$$2C_4H_9SiHCl_2 \longrightarrow C_4H_9SiCl_3 + C_4H_9SiH_2Cl. \qquad (6)$$

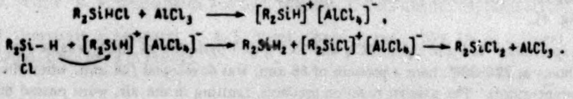
This reaction proceeds with greater difficulty and requires a larger amount of $AlCl_3$ than in the case of $C_2H_5SiHCl_2$.

The distillation of diethylchlorosilane with 9 mole % $AlCl_3$ results in disproportionation by the scheme

$$2(C_2H_5)_2SiHCl \longrightarrow (C_2H_5)_2SiCl_2 + (C_2H_5)_2SiH_2. \qquad (7)$$

Here the conversion of the diethylchlorosilane is 77%. The yield of diethylsilane is about 50%, and that of diethyldichlorosilane is up to 80%. This reaction is a new method for the convenient synthesis of dialkylsilanes.

The mechanism of the reaction for the conjugated hydrogenation-halogenation of alkylchlorohydrosilanes in the presence of aluminum chloride is apparently based on the migration of the hydride-ion from the silicon atom to the ionized complex of the halosilane with $AlCl_3$, and can be depicted by the following scheme



$$R_2SiHCl + AlCl_3 \longrightarrow [R_2SiH]^+[AlCl_4]^-,$$

$$\underset{\displaystyle Cl}{R_2Si}-H + [R_2SiH]^+[AlCl_4]^- \longrightarrow R_2SiH_2 + [R_2SiCl]^+[AlCl_4]^- \longrightarrow R_2SiCl_2 + AlCl_3.$$

EXPERIMENTAL

Starting reagents. Aluminum chloride – anhydrous, purified product of the "Converter" plant; ferric chloride – anhydrous, pure Kahlbaum preparation. Ethyldichlorosilane was obtained by the fractionation through a column of a mixture of ethylchlorosilanes, obtained by direct synthesis from Si and C_2H_5Cl; b.p. 74.5-75.5°. Butyldichlorosilane * was obtained in the same manner as $C_2H_5SiHCl_2$ by the direct synthesis of a mixture of butylchlorosilanes [5]; b.p. 126-129°. Diethylchlorosilane was obtained by the reaction of ethyldichlorosilane with C_2H_5MgBr (mole ratio 1:1). B.p. 98.5-101°, n_D^{20} 1.4157.

Found %: Cl 29.5. $C_4H_{11}ClSi$. Calculated %: Cl 28.9

Analysis. Hydrolyzable chlorine in the alkylchlorosilanes was determined by titration of a weighed sample of the analyzed substance (0.1-0.2 g) in either dioxane or alcohol (15-20 ml) with aqueous alkali solution (0.1N), using bromophenol blue as indicator. Hydrogen on the silicon atom was determined volumetrically in the apparatus used for determination of the hydroxyl group by the Chugaev-Tserevitinov method, involving the treatment of a weighed sample of the alkylhalohydrosilane in dioxane with concentrated alkali. Silicon was determined as SiO_2 by the mineralization of a weighed sample of the alkylchlorosilane in alcohol with a mixture of oleum and fuming nitric acid (in a 1:1 ratio by volume).

Reaction of ethyldichlorosilane with aluminum chloride. The experiments made to study the transformations of ethyldichlorosilane on $AlCl_3$, were run the same in each series, for which reason we present only the more characteristic experiments.

1. In a distillation flask fitted with Vigreaux column was place 81.2 g of ethyldichlorosilane and 33.5 g (40 mole %) of $AlCl_3$. The mixture was distilled for 2 hours until the aluminum chloride began to sublime. The distillate was filtered from mechanically entrained $AlCl_3$, and then it was distilled through a column with an efficiency of 15 theoretical plates. Here we obtained 7.3 g of ethylchlorosilane with b.p. 41-45° (% Cl 39.4).

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* The compound was kindly supplied by N. P. Smetankina, for which the authors express their gratitude.

45.9 g of unreacted ethyldichlorosilane and 22 g of ethyltrichlorosilane with b.p. 97-98° (% Cl 64.9).

2. In a round-bottomed flask, fitted with reflux condenser, was placed 61.7 g of ethyldichlorosilane and 32 g (50.2 mole %) of AlCl$_3$. The mixture was boiled for 8 hours, after which it was distilled. Fractional distillation of the distillate gave 0.1 g of ethylchlorosilane, 27.9 g of unreacted ethyldichlorosilane and 22.3 g of ethyltrichlorosilane with b.p. 97-98° (% Cl 64.8).

3. 200 g of ethyldichlorosilane and 40 g (19.4 mole %) of AlCl$_3$ was placed in a 0.5 liter steel autoclave. The autoclave was heated for 15 hours at 248-262°. Collection of the gaseous reaction products over water resulted in an explosion; the glass gasometer was found to be covered with a yellow-brown deposit, which dissolved in alkali with the liberation of a combustible gas (hydrogen). When the autoclave was opened a violent explosion occurred, leading to a loss of most of the condensate, as a result of which the product was not fractionated.

In a second experiment 137 g of ethyldichlorosilane and 6.9 g (4.9 mole %) of AlCl$_3$ was heated in a 225-ml autoclave for 40 hours at 230-240° and a maximum pressure of 50 atm. (22 atm. at room temperature). The gaseous products, showing spontaneous ignition in the air, were slowly dribbled into a trap, cooled to -80°, which was connected to another trap, containing a saturated solution of iodine in CCl$_4$, and then to a gasometer. The gas failed to enter either the gasometer or the liquid trap. The products, condensing in the low-temperature trap, exploded on coming in contact with the air. Fractionation of the condensate (127 g), filtered from AlCl$_3$, in a stream of dry nitrogen through a column with an efficiency of 20 theoretical plates gave the following fractions: 1st, 42-45°, 7.2 g, ethylchlorosilane (% Cl 38.9, calculated 37.5); 2nd, 45-74°, 3.9 g; 3rd, 74-77°, 50.1 g, unreacted ethyldichlorosilane (% Cl 54.6); 4th, 77-96°, 9.2 g; 5th, 96-98°, 28.4 g, ethyltrichlorosilane (% Cl 64.7); 6th, 98-128°, 3.1 g; 7th, 128-132°, 5.5 g, diethyldichlorosilane (% Cl 46.0); residue 12.4 g (Fig. 4).

In a third experiment 134 g of $C_2H_5SiHCl_2$ and 13.3 g (9.7 mole %) of AlCl$_3$ was heated in the 225-ml autoclave for 16 hours at 226-236°; here a pressure of 56 atm. was developed (24 atm. when the reaction was cooled to room temperature). The gaseous reaction products, igniting in the air, were passed through a trap containing a saturated solution of iodine in CCl$_4$, and then were collected in a gasometer over water. In measure with gas passage the trap contents became decolorized, in which connection fresh portions of the solution were added to the trap. The gas collected in the gasometer, in an amount of 740 ml, consisted almost entirely of hydrogen with a small amount of a silicon hydride of unknown composition as impurity (the presence of the impurity was established by an increase in the volume of the gas taken for analysis when it was passed through concentrated alkali solution, which can be explained only by an alkaline cleavage of the Si-H bond). The trap contents (164.5 g) were subjected to distillation, in which connection the following fractions were isolated : 1st 58.5 − 61°, 7.7 g; 2nd 61 − 63°, 100.5 g; 3rd 63 − 73°, 26.6 g; 4th 73 − 76°, 15.9 g; The 4th fraction was original CCl$_4$. The 2nd fraction was washed twice with sodium thiosulfate solution, then with water, and dried over CaCl$_2$. The product distilled completely in the range 61.2-62° (764.5 mm) and had d_4^{20} 1.4960 and n_D^{20} 1.4465, which agrees with the literature data for chloroform. The condensate from the autoclave was filtered from AlCl$_3$ and then fractionated in a stream of dry nitrogen through a column. The obtained products were the same as those described above. The properties of the obtained disproportionation products of ethyldichlorosilane are given in Table 3.

Reaction of ethyldichlorosilane with FeCl$_3$ was run under the same conditions as in the corresponding experiments with AlCl$_3$. In all of the experiments hardly any change in the $C_2H_5SiHCl_2$ was observed.

Reaction of butyldichlorosilane with AlCl$_3$. A mixture of 66.1 g of $C_4H_9SiHCl_2$ and 28 g (50 mole %) of AlCl$_3$ was distilled. The distillation was complicated by the sublimation of aluminum chloride, leading to contamination of the distillate and the loss of high-boiling products. Distillation of the distillate (47.8 g), filtered from AlCl$_3$, gave the following fractions: 1st, to 102°, 0.2 g; 2nd, 102-110°, 3.1 g — butylchlorosilane (% Cl 30.3; calcd. 28.9); 3rd, 110-125°, 12.7 g; 4th 125-130°, 28.7 g — unreacted butyldichlorosilane; 5th, 130-143°, 1.4 g; 6th, 143-146°, 0.6 g — butyltrichlorosilane (% Cl 54.0; Calcd. 55.5).

Reaction of diethylchlorosilane with AlCl$_3$. 30.9 g of $(C_2H_5)_2SiHCl$ was distilled from 3.1 g (9.2 mole %) of AlCl$_3$ in a flask fitted with a Vigreaux column. Fractional distillation of the distillate gave 3.8 g of diethylsilane with b.p. 54-57° and n_D^{20} 1.3940, 7.0 g of unreacted diethylchlorosilane and 12.3 g of diethyldichlosilane with b.p. 129-130° and n_D^{20} 1.4313.

SUMMARY

1. The reaction of ethyldichlorosilane and butyldichlorosilane with aluminum chloride and ferric chloride was studied. It was established that the distillation of ethyldichlorosilane with aluminum chloride leads to its disproportionation into ethylchlorosilane and ethyltrichlorosilane. Butyldichlorosilane reacts in a a similar manner, but at a slower rate. When the reaction is run at 230° and a pressure of 50 atm. the reaction products contain ethylchlorosilane, ethyltrichlorosilane, diethyldichlorosilane and explosive gaseous products, the latter reducing carbon tetrachloride to chloroform in the presence of iodine. The reaction does not go with ferric chloride under the studied conditions.

2. The previously unknown ethylchlorosilane was obtained and characterized.

3. It was shown that diethylchlorosilane in the presence of aluminum chloride disproportionates into diethylsilane and diethyldichlorosilane. This reaction is a new method for the synthesis of dialkylsilanes.

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REACTION OF TRIETHYLSILANE WITH ALKYL HALIDES

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It was established [1] that in the reaction of triethylsilane with 1-chlorohexane, 1-chloro-2,2-dimethylpropane and 1-chloro-3,3-dimethylbutane in the presence of $AlCl_3$ the exothermic reaction takes place:

$$(C_2H_5)_3SiH + RCl \xrightarrow{AlCl_3} (C_2H_5)_3SiCl + RH.$$

In the case of all three chloroalkanes the yield of $(C_2H_5)_3SiCl$ was 70-90%, in which connection n-hexane was obtained from the 1-chlorohexane, while the other two chloroalkanes gave not the postulated neopentane and neohexane, but instead the isomeric isopentane and 2,3-dimethylbutane. The isomerization should be regarded as being due to the catalystic influence of $AlCl_3$. A similar reaction of trialkylsilanes with carboxylic acid halides was observed by Jenkins and Post [2]:

$$R_3SiH + R'COX \longrightarrow R_3SiX + R'CHO,$$

where $R=C_2H_5$, $C_6H_5CH_2$; $R'=C_6H_5$, $p\text{-}C_2H_5OC_6H_4$, o-& $p\text{-}ClC_6H_4$; $X=Cl$ or Br.

For the most part the reaction proceeds with simple boiling of the reactants, but benzoyl chloride and o- and p-chlorobenzoyl chlorides do not react with $(C_2H_5)_3SiH$ in the absence of $AlCl_3$.

M. G. Voronkov and Yu. I. Khudobin [3] revealed that the reaction of triethylsilane with iodine in the presence of AlI_3, leading to the formation of $(C_2H_5)_3SiI$, should not be run in CCl_4 medium, since in this case a mixture of triethyliodosilane and triethylchlorosilane is obtained. However, it is not clear whether the $(C_2H_5)_3SiCl$ is formed as the result of replacement of iodine by chlorine between the $(C_2H_5)_3SiI$ and CCl_4, or whether it is due to catalytic reaction – between the triethylsilane and carbon tetrachloride.

Westermark [4] states that the 15 hour boiling of a mixture of $(C_2H_5)_3SiH$ and allyl bromide in the absence of any catalyst results in the quantitative reaction:

$$(C_2H_5)_3SiH + CH_2{=}CHCH_2Br \longrightarrow (C_2H_5)_3SiBr + CH_2{=}CHCH_3.$$

The reaction of triethylsilane with n-propyl bromide or with methyl β-bromopropionate proceeds with a lower yield of the triethylbromosilane. However, we were unable to reproduce Westermark's results [4]. We failed to observe any changes in the starting substances when we boiled a mixture of triethylsilane with allyl bromide or with n-propyl bromide for 17 hours in the absence of a catalyst. On the other hand, catalytic amounts of anhydrous aluminum chloride (0.8-1.2 mole %) cause the exothermic reaction of conjugated hydrogenation-halogenation to proceed violently even in the cold. We also studied the reaction of triethylsilane with isopropyl bromide, n-butyl bromide, 1,2-dibromoethane, ethyl iodide, allyl chloride, n-propyl chloride and isopropyl chloride, and in addition, the reaction of methyldipropylsilane with cyclohexyl chloride. In all cases in the presence of $AlCl_3$ the exchange of hydrogen by halogen proceeded with an 85-100% yield of the trialkylhalosilane (with the exception of methyldipropylchlorosilane, the yield of which was 70%). The reaction begins in the cold, but requires prolonged heating for its completion. The reaction rate of the trialkylsilanes with organic halides increases with increase in the mobility of the halogen atom in the latter. Thus in the series $C_2H_5X' -$ iso-$C_3H_7X -$ n-C_3H_7X under similar conditions, the time required to complete the reaction increases in the indicated order. A change in the character of the halogen atom (chlorine, bromine or iodine) for a given hydrocarbon radical exerts a lesser influence on the reaction rate. In the case of aromatic halides (C_6H_5Cl or C_6H_5Br) the reaction fails to go even when they are boiled with $(C_2H_5)_3SiH$ and $AlCl_3$ for several hours. A difference in the behavior of the aliphatic and aromatic halides should be regarded as being due to the lesser mobility of the halogen atoms in the latter. In its reaction with $(C_2H_5)_3SiH$, 1,2-dibromoethane replaces both of its halogen atoms by hydrogen simultaneously. In the reaction of triethylsilane with allyl halides the yield of hydrocarbon (propylene) is considerably lower than in the case of the saturated alkyl halides. In addition, tarry products are formed together with the propylene. Evidently, here there occurs polymerization of the propylene in statu nascendi under the influence of $AlCl_3$. The experimental results are summarized in Table 1.

TABLE 1

Reaction of Trialkylsilanes With Alkyl (Alkenyl) Halides in the Presence of 0.8-1.2 Mole % $AlCl_3$.

Expt. Nos.	R_3SiH	$R'X$*	Reaction time (in hours)	Yield (in %)	
				$R'H$	R_3SiX
1	$(C_2H_5)_3SiH$	C_2H_5Cl	1.0	20.4	94.4
2	$(C_2H_5)_3SiH$	iso-C_3H_7Cl	3.75	90.7	87.3
3	$(C_2H_5)_3SiH$	n-C_3H_7Cl	5.0	85.9	85.9
4	$(C_2H_5)_3SiH$	C_2H_5Br	1.75	28.6	99.7
5	$(C_2H_5)_3SiH$	iso-C_3H_7Br	2.75	93.4	89.1
6	$(C_2H_5)_3SiH$	n-C_3H_7Br	4.25	96.2	94.1
7	$(C_2H_5)_3SiH$	n-C_4H_9Br	—	—	>77.0
8	$(C_2H_5)_3SiH$	sym-$C_2H_4Br_2$	2.8	—	90.5
9	$(C_2H_5)_3SiH$	C_2H_5J	3.2	95.9	87.6
10	$CH_3(C_3H_7)_2SiH$	cyclo-$C_6H_{11}Cl$	2.0	59.5	69.2

As a result, the reaction for the exchange of hydrogen and halogen between trialkylsilanes and organic halide derivatives, proceeding under the influence of aluminum chloride, has a general character and can be depicted by the equation

$$R_3SiH + R'X \xrightarrow{AlCl_3} R_3SiX + R'H,$$

where: R = alkyl, R' = alkyl, alkenyl or alicyclic radical, and X = Cl, Br or I.

The exothermic character of the reaction is fully justified thermodynamically: the gain in the bond energy in the exchange reaction of Si-H with C-Cl, C-Br and C-I is respectively 30.6, 25.3 and 21.1 kcal./g-mole [5]. The mechanism of the reaction can be depicted as follows

$$R'X + AlX_3 \longrightarrow [R']^+ [AlX_4]^-,$$
$$R_3SiH + [R']^+ [AlX_4]^- \longrightarrow R'H + [R_3Si]^+ [AlX_4]^-,$$
$$[R_3Si]^+ [AlX_4]^- \longrightarrow R_3SiX + AlX_3.$$

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* In all cases, except Expt. No. 8, the mole ratio of the reactants was 1:1. In expt. No. 8 the mole ratio of R_3SiH to $R'X$ was 2:1.

EXPERIMENTAL

Starting reagents. Triethylsilane was obtained by the reaction of ethyldichlorosilane with either C_2H_5MgBr or C_2H_5MgI (mole ratio 1:2).

B.p. 107.1° (750.5 mm), n_D^{20} 1.4120, d_4^{20} 0.7316.

Methyldipropylsilane was obtained by the reaction of methyldichlorosilane with n-C_3H_7MgBr (mole ratio (1:2).

B.p. 125.9° (743 mm), n_D^{20} 1.4132, d_4^{20} 0.7330.

The starting organic halide derivatives were commercially pure. The aluminum chloride was anhydrous, the purified product of the "Converter" plant.

Reaction of triethylsilane with alkyl and alkenyl halides. Reaction of $(C_2H_5)_3SiH$ with allyl bromide. In a round-bottomed flask, fitted with thermometer and reflux condenser, was placed 24.2 g of C_3H_5Br and 23.2 g of $(C_2H_5)_3SiH$. The mixture was boiled for 17 hours, in which connection the boiling point of the mixture did not rise above 83°. Fractional distillation of the reaction mixture yielded unchanged triethylsilane and allyl bromide. In a similar experiment, after cooling to 0° , 1.3 g of anhydrous $AlCl_3$ was added to the reaction mixture. A violent reaction began immediately, accompanied by self-heating to 110° and the copious evolution of a gas, and leading to the loss (due to ejection) of a substantial portion of the reaction mixture. * In a second experiment,to a mixture of 17.4 g of triethylsilane and 0.3 g of $AlCl_3$, cooled to -8°, was added 18.2 g of allyl bromide in 45 minutes. Here the temperature of the reaction mixture was kept below 45°. To complete the reaction the mixture was heated until its boiling point ceased to rise (162°), and after cooling it was filtered from $AlCl_3$ and distilled from a flask fitted with a Vigreaux column. We obtained 29.1 g of triethylbromosilane with b.p. 162-166°. The residue in the flask was a dark-brown tar. During the reaction we collected 0.96 liter of gas, the bromination of which led to obtaining 1,2-dibromopropane with b.p. 142° (745.6 mm) and n_D^{20} 1.5200, which agrees with the literature data. The reaction of triethylsilane with n-propyl bromide, isopropyl bromide, 1,2-dibromoethane, ethyl iodide, allyl chloride, n-propyl chloride and isopropyl chloride was run under conditions similar to those used in the case of allyl bromide.

Reaction of $(C_2H_5)_3SiH$ with n-butyl bromide. To a mixture of 23.2 g of $(C_2H_5)_3SiH$ and 0.5 g of $AlCl_3$, cooled to 0°, was added 27.4 g of n-butyl bromide. The violent reaction that instantly developed here, proceeding with self-heating of the mixture and the evolution of a gas, and accompanied by the loss of part of the reaction mixture, was ended in several minutes. Distillation of the remaining portion of the products gave 30 g of triethylbromosilane with b.p. 161-164°. The yield of $(C_2H_5)_3SiBr$, despite the losses, was 77%.

Reaction of triethylsilane with chloro- and bromobenzene. A mixture of 17.4 g of $(C_2H_5)_3SiH$, 23.6 g of C_6H_5Br and 0.5 g of $AlCl_3$ was heated at the boil (134°) for 2 hours. Distillation of the reaction mixture through a column with an efficiency of 20 theoretical plates gave back the unchanged starting products. Similar results were obtained when a mixture of 17.4 g of triethylsilane, 16.9 g of chlorobenzene and 0.5 g of $AlCl_3$ was boiled for 4 hours.

Reaction of methyldipropylsilane with cyclohexyl chloride. To a mixture, composed of 19.5 g of $CH_3(C_3H_7)_2SiH$ and 0.5 g of $AlCl_3$, was added at room temperature 16.8 g of cyclohexyl chloride. That reaction began here could be judged by the self-heating of the mixture to 40°. The mixture was heated for 2 hours until a constant boiling point had been established (116°). Distillation of the reaction mixture through a column gave 7.5 g of cyclohexane: b.p. 80.6° (746.8 mm), n_D^{20} 1.4300, d_4^{20} 0.7847; we also obtained 17.1 g of methyldipropylchlorosilane.

The properties of the obtained trialkylhalosilanes are given in Table 2.

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* A similar phenomenon was observed in the reaction of $(C_2H_5)_3SiH$ with n-C_3H_7Br.

TABLE 2

Properties of Trialkylhalosilanes

Formula of the compound	Boiling point	Pressure (mm)	d_4^{20}	n_D^{20}	MR_D		Halogen content (in %)	
					found	calculated	found	calculated
$(C_2H_5)_3SiCl$	144.7°	762.6	0.8877	1.4310	43.95	43.70	22.97, 23.15	23.52
$(C_2H_5)_3SiBr$	163.3	753.7	1.1450	1.4570	46.42	46.67	41.45, 41.53	40.94
$(C_2H_5)_3SiI$	188.0	751.0	1.3532	1.4957	52.26	52.28	52.41, 52.49	52.41
$CH_3(C_3H_7)_2SiCl$	158.8	747.2	0.8785	1.4300	48.45	48.43	21.43, 21.45	21.52

SUMMARY

The reaction of trialkylsilanes with alkyl, cycloalkyl, alkenyl and aryl halides was studied. It was established that this reaction does not go in the absence of a catalyst. Catalytic amounts of anhydrous aluminum chloride cause the exothermic reaction of conjugated hydrogenation-halogenation to proceed violently even in the cold, leading to the formation of the corresponding hydrocarbon and trialkylhalosilane. The yield of the latter in the case of the alkyl and alkenyl halides reaches 85-100%. The investigated reaction can be used for the synthesis of trialkylhalosilanes and for the reduction of aliphatic and alicyclic halide derivatives.

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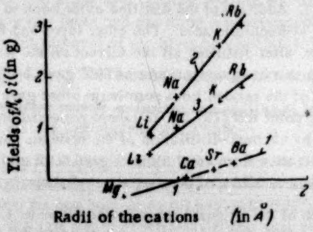
DEPENDENCE OF THE YIELDS OF TETRASUBSTITUTED ALKYL-AND ARYLMONOSILANES ON THE VALUES OF THE CHARGES AND RADII OF THE CATIONS OF SALTS OF FLUOSILICIC ACID

G. V. Mekoks and E. M. Soshestvenskaya

One of the simplest methods for the laboratory preparation of tetraalkyl- and tetraarylmonosilanes was proposed by E. M. Soshestvenskaya [1]. This method was also used by Z. Manulkin [2] and S. Manulkin with F. Yakubova [3]. Recently the suitability of similar reactions for the synthesis of organoboron compounds was demonstrated by A. N. Nesmeyanova and co-workers[4]. As is evident from the studies of E. Soshestvenskaya [5], the magnesium salt of fluosilicic acid is not suitable for the synthesis of tetrasubstituted monosilanes, while the reaction involving the calcium and barium salts of fluosilicic acid proceeds with great difficulty. As can be seen from our experiments, the corresponding strontium salt behaves in the same manner as the latter salts, which is explained by the influence of the magnitude of the cation charge of the fluosilicate on its ability to react with mixed organomagnesium compounds (the mobility of the fluorine atoms in the fluosilicate molecule decreases sharply with increase in the cation charge).



Dependence of the yields of R_4Si on the values of the radii of the cations of salts of fluosilicic acid.
1 and 2 – $C_{28}H_{28}Si$, 3 – $C_8H_{20}Si$.

A comparison of the yields of tetrabenzylmonosilane in the reaction of the salts of fluosilicic acid with benzylmagnesium chloride with the radii of the cations of these salts reveals a linear relationship between the examined values (Figure).

The reaction was run by heating a mixture of 0.02 mole of each of the used fluosilicates with 0.0808 mole of benzylmagnesium chloride for one hour at 160-170° (bath temperature). The point, corresponding to magnesium, was found by extrapolation and lies in the region of negative yields, which serves to explain the peculiar behavior of the corresponding fluosilicate.

The found rule is also valid in the reaction of benzylmagnesium chloride with the corresponding lithium, sodium, potassium and rubidium salts, and also in the similar reaction of the latter with ethylmagnesium bromide. In order to achieve a practical carrying out of the reaction it is very important to maintain a constant temperature regime. The reaction involving potassium and rubidium fluosilicates proceeds with strong self-heating, and if timely and sufficient cooling is not employed the temperature rapidly rises beyond the limits of the established range. Proceeding from found rules, it follows that the use of potassium salts in preference to sodium salts is to be recommended for reactions involving substitution on atoms or groups of atoms found in the inner sphere of complex salt molecules, possessing the cations in the outer sphere. If the cost of the starting substance is not a decisive factor, then it is desirable to use rubidium salts for the same purpose. The frequent use of potassium by various authors for reactions involving complex salts finds a simple explanation in the light of the facts given above. We are continuing our study of the reaction of the alkali metal fluosilicates with n-propylmagnesium bromide, n-butylmagnesium bromide, n-butylmagnesium chloride, n-amylmagnesium bromide, phenylmagnesium bromide and benzylmagnesium bromide for the purpose of establishing the application scope of the found rule.

EXPERIMENTAL

Reaction of benzylmagnesium chloride with salts of fluosilicic acid. The Grignard reagent, prepared from 55.19 g of benzyl chloride, 11.56 g of magnesium and 270 ml of absolute ether was used for all of the first five experiments described below; here for each experiment it was taken in aliquots corresponding to 10.22 g of consumed benzyl chloride, 2.14 g of magnesium and 50 ml of absolute ether. The fluosilicic salts were ground well in a mortar, sifted through a screen, and dried in a vacuum-desiccator over sulfuric acid.

1. Reaction with lithium fluosilicate. The Grignard reagent was poured into an Erlenmeyer flask containing 3.12 g of lithium fluosilicate. After distilling off the ether on the water bath the residual product was heated for 1 hour in an oil bath, heated to 160-170° (the temperature inside the flask did not exceed 126°). The cooled reaction product, having a slightly green color, after adding the distilled ether, was decomposed under cooling by the gradual addition of 20 ml of 16% hydrochloric acid. The floating, slightly colored ether layer was separated, while the water layer, containing a small amount of deposit, was extracted together with the latter several times with diethyl ether (55 ml). The extracts together with the ether layer gave 2.80 g of pale yellow liquid after distilling off the ether, which partially crystallized on standing. Its distillation from a metal bath gave 0.42 g of nearly colorless liquid (109-200°) with a benzaldehyde odor and 2.22 g of residue, which crystallized on cooling; recrystallization of the residue from ethyl alcohol gave 0.86 g of colorless crystals of tetrabenzylsilane with m.p. 127.5°.

Found %: C 85.60; H 7.21; Si 7.10. $C_{28}H_{28}Si$. Calculated %: C 85.65; H 7.19; Si 7.16.

The mother liquor after distilling off the alcohol was vacuum-distilled (12 mm) to give 0.62 g of nearly colorless liquid, which crystallized on cooling, and 0.45 g of residue, from which individual compounds could not be isolated. From the distilled substance we isolated 0.14 g of dibenzyl with m.p. 52.5°.

2. Reaction with sodium fluosilicate. The Grignard reagent was added to 3.76 g of sodium fluosilicate, contained in an Erlenmeyer flask. After distilling off the ether the residue was heated in an oil bath at 160-170° for 1 hour (the temperature inside the flask did not exceed 126°). Addition of the distilled ether back to the solid residue was followed by decomposition with 20 ml of 16% hydrochloric acid. The ether layer and the extracts (35 ml), obtained in the extraction of the water layer with ether, after distilling off the solvent on the water bath, left a yellow oily liquid as residue. Distillation of the latter up to a head temperature of 200° gave 1.27 g of a colorless fraction, containing toluene, while recrystallization of the residue from petroleum ether gave 1.43 g of substance, which proved to be, judging by the mixed melting point test (127.5°), tetrabenzylmonosilane. The mother liquor after distilling off the petroleum ether, followed by vacuum-distillation of the residue, gave 0.58 g of a fraction with b.p. 95-127° (5 mm), which after recrystallization from ethyl alcohol gave 0.22 g of dibenzyl (m.p. 52.5°). From the distilled product (0.51 g) we isolated another 0.16 g of pure tetrabenzylsilane.

3. Reaction with potassium fluosilicate. The next portion of the Grignard reagent was added to 4.40 g of potassium fluosilicate. After distilling off the ether on the water bath the residue was very carefully heated in an oil bath. The bath was removed immediately when the temperature inside the flask showed a tendency to rise rapidly; the flask was immediately cooled with a stream of air. The temperature in the flask was kept below 129°. Heating in the oil bath (up to 160-170°) was continued for 1 hour. After adding back the distilled ether the reaction product was decomposed with 25 ml of 10% hydrochloric acid. A noticeable heat effect was not observed. The ether layer was decanted, while the water layer, together with a copious white precipitate, was extracted 5 times with ether (90 ml). From the oily liquid, remaining after removal of the ether, there distilled up to 200° 0.8 g of a liquid fraction. Recrystallization of the crystalline residue (5.22 g) from ethyl alcohol gave 2.78 g of crude tetrabenzylsilane, the recrystallization of which gave 2.38 g of pure substance with m.p. 127.5°. From the oil (2.62 g), obtained as a residue after distilling off the solvent from the mother liquors, we isolated 0.19 g of dibenzyl (m.p. 52.5°) and another 0.21 g of pure tetrabenzylsilane.

4. Reaction with rubidium fluosilicate. The fourth portion of the Grignard reagent was added to a flask containing 6.26 g of rubidium fluosilicate, obtained, in accord with the directions of Stolba [6], by the reaction of rubidium chloride with copper fluosilicate. After distilling off the ether the residue was heated for 1 hour in an oil bath (160-170°). As soon as the temperature inside the Erlenmeyer flask began to rise rapidly the flask

was cooled with a stream of air, which made it possible to keep the temperature in the reaction mixture from rising above 130°. After cooling, the distilled ether was poured back in the flask, and then followed decomposition with17 ml of 10% hydrochloric acid, decantation of the ether layer, repeated extraction with diethyl ether, distillation of the latter on the water bath and, finally, distillation from a metal bath. We obtained 1.03 g of nearly colorless oily liquid (b.p. up to 200°), containing dibenzyl, toluene and benzaldehyde. The residue (4.67 g) crystallized on cooling and gave, after recrystallization from 65 ml of ethyl alcohol, 3.00 g of pure tetrabenzylsilane (m.p. 127.5°). From the mother liquor after distilling off the alcohol, vacuum-distillation (12 mm) of the residue, and subsequent recrystallization from ethyl alcohol, we extracted 0.30 g of dibenzyl with m.p. 52.5°.

5. Reaction with strontium fluosilicate. The fifth portion of the Grignard reagent was added to 4.59 g of strontium fluosilicate. After distilling off the ether on the water bath, heating in an oil bath at 160-170° for 1 hour, adding back the distilled ether to the cooled mass, decomposition with 20 ml of 10% hydrochloric acid, decantation of the ether layer, two extractions with ether (10 ml), distilling off first the ether, and then the fraction (3.40 g) boiling up to 200°, separating the liquid from the partially crystallized residue (2.32 g) by suction-filtration and, finally, washing the residue with ether, we obtained 0.21 g of crude tetrabenzylsilane with m.p. 124-125°. After recrystallization from ethyl alcohol we obtained 0.19 g of pure compound. The mixed melting point was 127.5°. We also isolated 0.29 g of dibenzyl with m.p. 52.5° from the reaction products.

Reaction of ethylmagnesium bromide with fluosilicates. For the next experiments we used the Grignard reagent prepared from 41.84 g of ethyl bromide, 9.36 g of magnesium and 125 ml of absolute ether (yield 94.3%). The fluosilicates were crushed well in a mortar, sifted through a screen, and dried in a vacuum-desiccator over sulfuric acid.

1. Reaction with lithium fluosilicate. To an Erlenmeyer flask, containing 3.12 g of lithium fluosilicate, was added 30.6 ml of the Grignard reagent, containing 10.77 g of ethylmagnesium bromide. Then the ether was distilled on the water bath, the mixture heated in an oil bath (160-170°) for 1 hour, the distilled ether, containing tetraethylsilane, poured back in the flask, the walls of the flask receiver rinsed with 5 ml of ether to remove the last traces of tetraethylsilane, the reaction products decomposed with 25 ml of 10% hydrochloric acid, added in drops with constant shaking and cooling with ice water, and finally, the ether layer was separated from the water layer and the latter was extracted with ether (10 ml). The slightly colored oily liquid, remaining after careful removal of the ether by distillation (0.5 g), proved to be tetraethylsilane.

Found %: C 66.31; H 14.05. $C_8H_{20}Si$. Calculated %: C 66.55; H 13.98.

We were unable to isolate any additional tetraethylsilane from the ether distillate. Consequently, the yield of the tetraethylsilane was 17.3%.

2. Reaction with sodium fluosilicate. We took 3.76 g of sodium fluosilicate and the same amount of ethylmagnesium bromide in ether solution as in the preceding experiment. Proceeding as before, the mixture was heated for one hour in an oil bath (160-170°), the distilled ether was added back to the cooled reaction product, the last traces of tetraethylsilane were removed with 5 ml of ether, then decomposition with 25 ml of 10% hydrochloric acid, separation of the ether layer from the water, two extractions of the water layer with diethyl ether (10 ml), and finally, the ether was distilled on the water bath. The undistilled tetraethylsilane (0.74 g) was mixed with the same substance (0.26 g), isolated in the fractional distillation of the distilled ether.

Found %: C 66.50; H 14.11. $C_8H_{20}Si$. Calculated %: C 66.55; H 13.98.

3. Reaction with potassium fluosilicate. To the flask containing 4.40 g of potassium fluosilicate was added 30.6 ml of the Grignard reagent. After distilling off the ether the mixture was heated for one hour in an oil bath (160-170°). A very rapid self-heating of the mixture was observed when the temperature inside the flask rose to 128°. The flask was cooled with a stream of air. Subsequent treatment of the reaction products was the same as in the previous case. After distilling off the ether from the ether layer and the ether extracts we isolated 1.40 g of tetraethylsilane and an additional 0.12 g from the fractional distillation of the distilled ether.

Found %: C 66.49; H 13.99; Si 19.41. $C_8H_{20}Si$. Calculated %: C 66.65; H 13.98; Si 19.41.

4. Reaction with rubidium fluosilicate. To 6.26 g of rubidium fluosilicate was added 30.6 ml of the ether solution of ethylmagnesium bromide: the ether was distilled off and the residue was heated in an oil bath (160-170°) for 1 hour. Pronounced foaming began when the temperature inside the flask rose to 103° and a copious white fog appeared. The bath was lowered and the flask was immediately cooled with a stream of air. Despite this, the temperature inside the flask rose to 129° in 3 minutes. On conclusion of heating the reaction products were worked up in the same manner as in the reactions with sodium and potassium fluosilicates. The decomposition with hydrochloric acid proceeded calmly. Distillation of the ether layer and ether extracts gave 1.55 g of tetraethylsilane and another 0.26 g of this compound was obtained from the fractional distillation of the distilled ether. The total yield was 62.7%.

Found %: C 66.52; H 14.02; Si 19.23. $C_8H_{20}Si$. Calculated %: C 66.55; H 13.98; Si 19.47.

SUMMARY

The reaction of lithium, sodium, potassium and rubidium fluosilicates with benzylmagnesium chloride and ethylmagnesium bromide was studied. It was established that the yields of tetrabenzylsilane and tetraethylsilane show a linear relationship to the radii of the cations of lithium, sodium, potassium and rubidium fluosilicates. It was shown that a similar relationship also exists in the reaction of benzylmagnesium chloride with calcium, strontium and barium fluosilicates, however an increase in the charge of the cations leads to a sharp reduction in the yields of the tetrasubstituted monosilane.

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SYNTHESIS OF SPASMOLYTINE, LABELED WITH RADIOACTIVE CARBON C^{14} IN THE CARBONYL GROUP

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The diphenylacetic ester of diethylaminoethanol (spasmolytine, difacil, trasentine $(C_6H_5)_2CHCOOCH_2CH_2N(C_2H_5)_2$ is an extremely effective antispasmodic, the pharmacological study of which has been the subject of a number of papers. One of the most fruitful pharmacological study methods is the method of "labeled atoms", frequently permitting a completely new evaluation of the processes proceeding in an organism. In 1955 Yu. V. Markova, L. N. Zenkova and M. N. Shchukina described the organolithium synthesis of p-aminobenzoic acid, labeled with radioactive carbon C^{14}, and of the corresponding novacaine compound [1]. For the purpose of continuing our pharmacological studies of the novocaine analog—spasmolytine, we undertook the synthesis in the living organism of spasmolytine, labeled with radioactive carbon C^{14} in the carbonyl group. The synthesis route was determined by the practicality of introducing radioactive atoms in the last stages of the process and by the best yields when calculated on the basis of the original radioactivity.

$$
\begin{gathered}
C_6H_5CH_2Cl + C_6H_6 \xrightarrow{AlCl_3} C_6H_5CH_2C_6H_5, \\
C_6H_5CH_2C_6H_5 + C_6H_5Na \longrightarrow C_6H_5CHNaC_6H_5, \\
C_6H_5CHNaC_6H_5 + C^{14}O_2 \longrightarrow (C_6H_5)_2CHC^{14}OONa, \\
(C_6H_5)_2CHC^{14}OONa + ClCH_2CH_2N(C_2H_5)_2 \longrightarrow (C_6H_5)_2CHC^{14}OOCH_2CH_2N(C_2H_5)_2.
\end{gathered}
$$

EXPERIMENTAL

β-Chlorodiethylaminoethane was obtained in known manner from diethylaminoethanol and thionyl chloride in chloroform medium. B.p. 50-52° (15-16 mm). To synthesize diphenylacetic acid, labeled with carbon C^{14}, we ran a series of experiments with inactive substances. Rejecting the organomagnesium synthesis, proving unsatisfactory in the present case, we settled on the organosodium synthesis, which assures an excellent yield of diphenylacetic acid [2]. The radioactivity was controlled with the aid of a β-counter.

Preparation of diphenylmethane. Diphenylmethane was obtained by the condensation of benzyl chloride with benzene in the presence of anhydrous aluminum trichloride. In a round-bottomed flask, fitted with reflux condenser, was placed 200 g of benzyl chloride, 1000 g of benzene and then in twenty portions was gradually added 80 g of anhydrous aluminum chloride. At the start the reaction was both spontaneous and violent; then the reaction mixture was heated for 6-7 hours on the boiling water bath. On conclusion of reaction water was added to the flask, and after drying over calcium chloride the benzene was removed by distillation from the benzene layer. The residue was fractionally distilled in vacuo. The obtained diphenylmethane had b.p. 134-136° (15-16 mm). Yield about 80 g.

Preparation of comminuted sodium. Six grams of metallic sodium and 60-70 ml of dry xylene was introduced into a three-necked flask. Then the mixture was heated to 110° in a rapid stream of dry pure nitrogen, after which a propeller stirrer (5000-6000 r.p.m) was inserted, which comminuted the molten metal into tiny particles. After cooling, the xylene was removed by suction, using a Schott funnel previously introduced into the reaction flask, and the comminuted sodium was washed in a nitrogen atmosphere with anhydrous benzene.

Preparation of diphenylsodiomethane. To 6 g of comminuted sodium, found in a nitrogen atmosphere, was added 15 g of chlorobenzene and 65 ml of dry benzene, and the mixture was stirred at 20-30° for 1 hour. After adding 17 g of diphenylmethane the reaction mixture was let stand at room temperature for 24 hours, after which it was heated for several hours on the water bath at 50-60°.

Preparation of diphenylacetic acid, labeled with radioactive carbon C^{14}. Well-dried carbon dioxide ($C^{14}O_2$ in admixture with CO_2) was slowly passed through the reaction mixture, containing the diphenylsodiomethane, for 7-8 hours at 60-70°. After passing nonradioactive carbon dioxide for a short time a test sample of the mixture ceased to show alkaline, which was conclusive proof that reaction was complete. Then the reaction mixture was poured into water, the water layer separated in a separatory funnel, and then acidified with sulfuric acid. The deposited diphenylacetic acid had a dirty-yellow color. The product was purified by recrystallization from hot water using activated carbon. The purified product was obtained as very fluffy white crystals with m.p. 136-137°. The weight yield was 13 g, and the radioactive yield was 50%.

Preparation of the diphenylacetic ester of diethylaminoethanol (spasmolytine), labeled with radioactive carbon C^{14}. The synthesis of spasmolytine was accomplished by the method described in the literature [3] with slight modifications. A mixture of 10 g of diphenylacetic acid, labeled with radioactive carbon C^{14} in the carboxyl group, 6.5 g of β-chlorodiethylaminoethane and 40 ml of acetone, dried over fused potash, was heated in a flask under reflux with vigorous shaking for 24 hours. On conclusion of reaction a stream of dry hydrogen chloride was passed through the reaction mixture for a short time, the obtained precipitate was separated, washed with cold acetone, and recrystallized from ethyl acetate. Spasmolytine hydrochloride was obtained as fine crystals, m.p. 113-114°, which agrees exactly with the literature data. Spasmolytine picrate has m.p. 143-144°, and the hydroiodide has m.p. 118-119°. The free base of the amino ester has b.p. 156-160° (6-8 mm). The radioactive yield of spasmolytine, calculated on the diphenylacetic acid, was 42%.

SUMMARY

1. Diphenylacetic acid, labeled with radioactive carbon C^{14} in the carboxyl group, was synthesized.

2. The diphenylacetic ester of diethylaminoethanol (spasmolytine), labeled with radioactive carbon C^{14} in the carbonyl group, was synthesized.

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** In Russian.

BROMINATION OF THIAZOLE DERIVATIVES WITH N-BROMOSUCCINIMIDE

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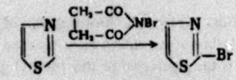
The bromination of heterocyclic compounds with N-bromosuccinimide has not been studied adequately. In the oxygen-containing heterocyclic series the method has been applied to furan [1], its derivatives [2], and to coumarin [3]. Of the nitrogen-containing heterocycles α and γ-picoline and quinaldine [4] have been studied, being brominated with N-bromosuccinimide in the side chain. The reaction between acridine and N-bromosuccinimide has also been described [5]. A thorough study was made of the bromination of thiophene [4] and its derivatives. Dittmer and co-workers [6], in studying the effect of benzoyl peroxide on the bromination of 2- and 3-methylthiophene, established that without a catalyst the ring is brominated, while when benzoyl peroxide is used the substitution is in the side chain.

The use of this method of bromination in the thiazole series is limited to the solitary case of the bromination of 2-methyl-5-ethoxythiazole to 2-methyl-4-bromo-5-ethoxythiazole in the presence of benzoyl peroxide [7]. In view of the fact that the bromination of thiazole derivatives with bromine is unsuccessful in nearly all cases, a further study of the possibility of applying the Wohl-Ziegler reaction to this class of compounds represents very great interest.

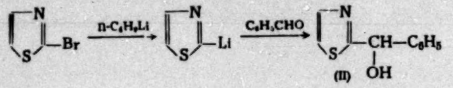
In this paper we give the results of brominating thiazole, 4-methylthiazole, 2,4-dimethylthiazole and 2,4,5-trimethylthiazole with N-bromosuccinimide. In the first two cases we used equimolar amounts of the thiazole compound and N-bromosuccinimide, while in the bromination of the 2,4-dimethyl- and 2,4,5-trimethylthiazole the reactants were taken in a 3 :1 ratio. The effect of benzoyl peroxide on the bromination of thiazole and 4-methylthiazole was also examined; however, in both cases its presence did not influence the reaction course. It should be mentioned that in many cases the reaction is markedly accelerated by the addition of benzoyl peroxide, and this permits brominating many compounds that fail to brominate in the absence of a catalyst [8]. There was substantial tar formation in all of the studied cases, which lowered the yields of the bromides.

The bromination of thiazole with N-bromosuccinimide permits isolating 2-bromothiazole (I) in 12.5% yield.



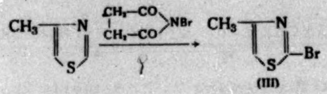
(I)

To establish its structure, the obtained substance was converted through the lithium compound to thiazolylphenylcarbinol (II), proving to be identical with the 2-thiazolylphenylcarbinol of [9].

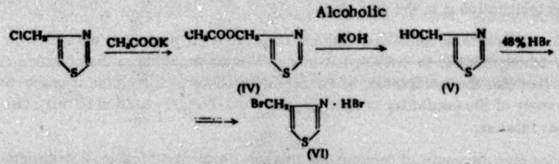


(II)

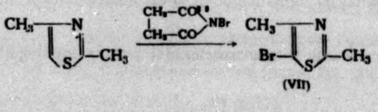
According to the literature [10], thiazole with bromine in the vapor phase at 250° also brominates in the 2 position. The reaction of N-bromosuccinimide with 4-methylthiazole results, the same as in the case of thiazole, in bromination in the 2 position with the formation of 4-methyl-2-bromothiazole(III), which was obtained as a liquid with b.p. 79-81° (20 mm), yield 26%. According to the literature the bromination of 4-methylthiazole with bromine cannot be accomplished [11].



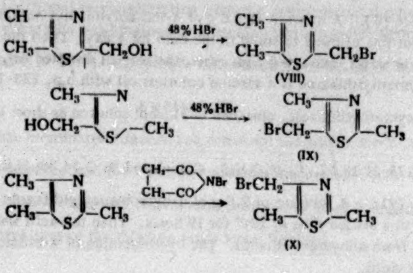
To prove the structure of the obtained bromide we prepared acetate (IV) from 4-chloromethylthiazole; the acetate was hydrolyzed and the 4-hydroxymethylthiazole (V) was brominated with hydrobromic acid. The 4-bromomethylthiazole hydrobromide (VI) obtained here had m.p. 192-193°, while the hydrobromide of 4-methyl-2-bromothiazole melted at 169-170°. The third direction for the bromination of 4-methylthiazole – the formation of 4-methyl-5-bromothiazole – is excluded, since the latter is a crystalline compound [12] (m.p. 138°).



The bromination of 2,4-dimethylthiazole with N-bromosuccinimide gives 2,4-dimethyl-5-bromothiazole (VII) in 74% yield. The structure of this bromide was proved by comparing its picrate with the picrate of 2,4-dimethyl-5-bromothiazole, obtained by the bromination of 2,4-dimethylthiazole with bromine.



As a result, with unsubstituted positions present the bromination of thiazole homologs with N-bromosuccinimide proceeds in the ring. When N-bromosuccinimide is reacted with a fully substituted thiazole compound – 2,4,5-trimethylthiazole – it is the hydrogen in the methyl group found in the 4 position that is replaced by bromine. To prove the structure of the obtained bromide we brominated 4,5-dimethyl-2-hydroxymethylthiazole and 2,4-dimethyl-5-hydroxymethylthiazole with hydrobromic acid. The nonidentity of the picroate of 4,5-dimethyl-2-bromomethylthiazole (VIII) with the picrate of the bromide obtained by us and of the hydrobromide of the latter with the hydrobromide of 2,4-dimethyl-5-bromomethylthiazole (IX) indicates that 2,5-dimethyl-4-bromomethylthiazole (X) is formed in the bromination of 2,4,5-trimethylthiazole with N-bromosuccinimide.



EXPERIMENTAL

2-Bromothiazole (I). A mixture of 10 g of thiazole [13], 21 g of N-bromosuccinimide [14] and 35 ml of dry carbon tetrachloride was heated on the water bath to 67°. A vigorous reaction began at this temperature, accompanied by frothing of the solvent, solution of the N-bromosuccinimide, and the separation of another precipitate that rapidly became tarry. Then the reaction mass was heated for 45 minutes, cooled, filtered, the filtrate washed with dilute sodium hydroxide solution, the solvent distilled off, and the residue vacuum-distilled. The yield of 2-bromothiazole with b.p. 70-75° (15 mm) was 2.4 g (12.5%). An ether solution of 1.64 g of the bromide was added to a cooled (−40°) ether solution of n-butyllithium, prepared from 0.25 g of lithium, 1.55 g of n-butyl chloride and 50 ml of ether. The brown reaction mixture was shaken in a nitrogen stream for 15 minutes, and then an ether solution of 1.1 g of benzaldehyde was added to it at −30°. The lighter colored reaction mass was shaken another 45 minutes, and then it was poured into dilute hydrochloric acid solution, cooled in ice. The acid layer was separated, neutralized with concentrated ammonia solution, extracted with ether, and the ether removed by distillation. The residue after recrystallization from benzine (b.p. 60-120°) had m.p. 104-107° and did not give a melting point depression when mixed with the 2-thiazolylphenylcarbinol (II) of [9], obtained in a similar manner from 2-bromothiazole.

Found %: C 62.90; H 4.84. $C_{10}H_9ONS$. Calculated %: C 62.79; H 4.74.

4-Methyl-2-bromothiazole (III). A mixture of 18 g of 4-methylthiazole [15], 32 g of N-bromosuccinmide and 50 ml of dry carbon tetrachloride was heated on the water bath to 60°. At this temperature the reaction mixture began to froth, the precipitate dissolved, and another rapidly-tarring precipitate separated. The reaction mass was heated another 30 minutes, then it was cooled, filtered, the solvent distilled off, and the residue vacuum-distilled. We obtained 8.3 g (26%) of 4-methyl-2-bromothiazole as a colorless liquid with b.p. 79-81° (20 mm), n_D^{20} 1.5775; d_{20}^{20} 1.7045.

Found %: C 26.98; H 2.35; N 7.82. C_4H_4NBrS. Calculated %: C 26.97; H 2.26; N 7.86

The hydrobromide of 4-methyl-2-bromothiazole has m.p. 169-170°.

Found %: C 18.36; H 2.07. $C_4H_5NBr_2S$. Calculated %: C 18.55; H 1.94

4-Thiazolylmethyl acetate (IV). A mixture of 5 g of 4-chloromethylthiazole, obtained from the hydrochloride [16], 7.5 g of freshly fused potassium acetate and 10 ml of glacial acetic acid was boiled for 2 hours. Then the reaction mass was treated with water, extracted with ether, the ether distilled off, and the residue vacuum-distilled. The yield of thick yellowish oil with b.p. 117-119° (14 mm) was 4.6 g (79%).

Found %: C 45.86; H 4.42. $C_6H_7O_2NS$. Calculated %: C 45.83; H 4.48.

The picrate of 4-thiazolylmethyl acetate, obtained in alcohol solution as slender yellow needles has, m.p. 129-131°.

Found %: C 37.10; H 2.50. $C_{12}H_{10}O_9N_4S$. Calculated %: C 37.38; H 2.61.

4-Hydroxymethylthiazole (V). A mixture of 4.6 g of 4-thiazolylmethyl acetate, 2.5 g of potassium hydroxide and 20 ml of alcohol was allowed to stand in the cold for a day. Then the solvent was distilled off, the residue was dissolved in water, extracted with ether, the solvent distilled off, and the residue vacuum-distilled. 4-Hydroxymethylthiazole is a viscous colorless oil with b.p. 123-125° (15 mm); yield 77.5%.

The picrate of 4-hydroxymethylthiazole, obtained in alcohol solution as short glistening yellow needles, has m.p. 158-159°.

Found %: C 35.07; H 2.75; N 16.17. $C_{10}H_8O_8N_4S$. Calculated %: C 34.88; H 2.34; N 16.26.

4-Bromomethylthiazole (VI). A mixture of 2.6 g of 4-hydroxymethylthiazole and 30 ml of 48% thiazole(VI) hydrobromic acid was heated in a sealed tube at 120° for 12 hours. Then the acid was distilled off, and the residue was recrystallized from anhydrous ethanol. The hydrobromide of 4-bromomethylthiazole with m.p. 192-193° was obtained in 33% yield.

Found %: C 18.57; H 2.31; N 5.26. $C_4H_5NBr_2S$. Calculated %: C 18.55; H 1.94; N 5.40.

2,4-Dimethyl-5-bromothiazole (VII). A mixture of 10 g of 2,4-dimethylthiazole [15], 5.3 g of N-bromosuccinimide and 10 ml of carbon tetrachloride was cautiously heated on the water bath at 50°. In 15 minutes a heavy precipitate of succinimide separated. The reaction mixture was cooled, filtered, the filtrate washed with dilute sodium hydroxide solution, the solvent distilled off, and the residue vacuum-distilled. The yield of substance with b.p. 75-80° (9 mm) was 74%.

The picrate, obtained in alcohol solution, had m.p. 104-105° and did not give a melting point depression with the picrate of 2,4-dimethyl-5-bromothiazole [17].

2,5-Dimethyl-4-bromomethylthiazole (X). A mixture of 30 g of 2,4,5-trimethylthiazole [15], 14.1 g of N-bromosuccinimide and 30 ml of carbon tetrachloride was heated at 50° for 15 minutes. The precipitate gradually dissolved and succinimide deposited. The reaction mass was cooled, filtered, the filtrate washed with dilute alkali solution, the solvent distilled off, and the residue repeatedly vacuum-distilled. The yield of colorless liquid with b.p. 86-90° (15 mm) was 21.6%. The completely pure bromide distills at 88-90° (15 mm), n_D^{20} 1.547, d_{20}^{20} 1.3383.

Found %: C 34.75; H 3.98; Br 38.73. C_6H_8NBrS. Calculated %: C 34.96; H 3.91; Br 38.77.

The picrate was obtained in alcohol solution as yellow prisms with m.p. 106.5-108°.

Found %: C 32.94; H 2.71. $C_{12}H_{11}O_7N_4BrS$. Calculated %: C 33.11; H 2.54.

The hydrobromide was obtained as glistening colorless needles with m.p. 190-191°.

Found %: N 4.75. $C_6H_9NBr_2S$. Calculated %: N 4.77.

When reacted with alkali 1 mole of the substance combines with 1 mole of alkali.

11.406 mg substance: 3.99 ml 0.01 N NaOH. Calculated: 3.97 ml 0.01 N NaOH.

4,5-Dimethyl-2-bromomethylthiazole (VIII). A mixture of 3 g of 4,5-dimethyl-2-hydroxymethylthiazole [18] and 30 ml of 48% hydrobromic acid was heated in a sealed tube at 120° for 12 hours. Then the acid was vacuum-distilled, the residue dissolved in water, the solution saturated with potash, the separated oil layer extracted with ether, and the ether removed by distillation. The residual brown oil could not be distilled in vacuo without decomposition, and consequently the substance was isolated as the picrate in alcohol solution. After repeated recrystallization from anhydrous ethanol the picrate was obtained as slender yellow needles (m.p. 101.5-103°), giving a melting point depression when mixed with the picrate of 2,5-dimethyl-4-bromomethylthiazole.

Found %: C 33.19; H 2.84; N 12.83; Br 18.38. $C_{12}H_{11}O_7N_4BrS$. Calculated %: C 33.11; H 2.54; N 12.89; Br 18.36.

2,4-Dimethyl-5-bromomethylthiazole (IX). A mixture of 3 g of 2,4-dimethyl-5-hydroxymethylthiazole (19] and 30 ml of 48% hydrobromic acid was heated in a sealed tube at 120° for 12 hours. Then the acid was vacuum-distilled, the residue treated with anhydrous ethanol, and the separated crystalline precipitate of the hydrobromide was filtered and washed with dry ether. The yield of hydrobromide with m.p. 131-135° was 38.3%. After additional recrystallization from the same solvent the hydrobromide of 2,4-dimethyl-5-bromomethylthiazole was obtained as glistening white needles with m.p. 134-135°.

Found %: C 25.16; H 3.24; Br 55.66. $C_6H_9NBr_2S$. Calculated %: C 25.10; H 3.16; Br 55.68.

SUMMARY

1. N-Bromosuccinimide brominates thiazole and 4-methylthiazole in the 2 position.
2. The reaction of N-bromosuccinimide with 2,4-dimethylthiazole yields 2,4-dimethyl-5-bromothiazole.
3. 2,4,5-Trimethylthiazole reacts with N-bromosuccinimide to yield 2,5-dimethyl-4-bromomethylthiazole.
4. Some new halo derivatives of the thiazole series were obtained.

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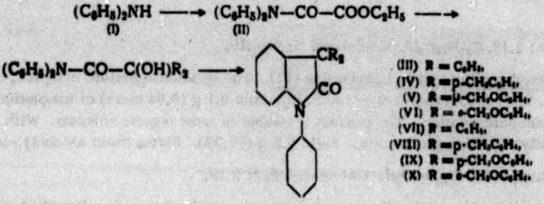
CHEMISTRY OF HETEROCYCLES

XXVIII. SYNTHESIS AND PROPERTIES OF 1-PHENYL-3,3-DIARYLOXINDOLES

P. A. Petyunin and V. S. Shklyaev

The present paper is a further development of our investigations on the transformation of the arylamides of hydroxycarboxylic acids into heterocyclic compounds [1]. It seemed of interest to elucidate the influence of a phenyl radical on the nitrogen in the arylamides of hydroxycarboxylic acids on their closure into a heterocycle, and together with that, to develop a method for the preparation of the N-phenyl derivatives of 3,3-diaryloxindoles. It should be mentioned that of the N-phenyl-3,3-diaryloxindoles only the 1,3,3-triphenyloxindole is described in the literature, which was obtained in small yield by the reaction of phenylmagnesium bromide with isatin, or by the Friedel-Crafts-Gustavson reaction from 3,3-dichlorooxindole and benzene [2].


$(C_6H_5)_2NH \longrightarrow (C_6H_5)_2N{-}CO{-}COOC_2H_5 \longrightarrow$
(I)
(II)
$(C_6H_5)_2N{-}CO{-}C(OH)R_2 \longrightarrow$
CR_2
CO
N
(III) $R = C_6H_5$,
(IV) $R = p\text{-}CH_3C_6H_4$,
(V) $R = p\text{-}CH_3OC_6H_4$,
(VI) $R = o\text{-}CH_3OC_6H_4$,
(VII) $R = C_6H_5$,
(VIII) $R = p\text{-}CH_3C_6H_4$,
(IX) $R = p\text{-}CH_3OC_6H_4$,
(X) $R = o\text{-}CH_3OC_6H_4$.

The reaction of ethyl chlorogyloxylate with diphenylamine (I) gave the ethyl ester of diphenyloxamic acid (II), which when reacted with organomagnesium compounds gives the diphenylamides of the corresponding diarylglycolic acids (III-VI) in good yields. The latter manifest halochromism and under the influence of mineral acids are converted in high yields into the N-phenyl derivatives of the 3,3-diaryloxindole (VII-X). Of interest is the fact that the oxindole ring is closed with considerably greater ease for the diphenylamides than for the anilides of the same diarylglycolic acids. Thus, for example, in substance (III) under the influence of concentrated sulfuric acid the heterocycle shows practically instantaneous closure. The oxindole ring shows closure under even milder conditions in the diphenylamides with electron-donor substituents in the phenyl radicals found at the carbonyl carbon. It was shown experimentally that (VIII) and (IX) can be obtained directly in the Grignard synthesis if the organomagnesium complex is decomposed with 10% hydrochloric acid. Diphenylamides (IV) and (V) are obtained only if the reaction mass is decomposed with saturated ammonium chloride solution. An easier closure of the heterocycle in the diphenylamides of diarylglycolic acids (III-VI) can probably be explained by an increase in the number of nucleophilic reaction centers, since here both of the benzene rings of the $(C_6H_5)_2$ N-group can participate in the closure of the oxindole ring.

EXPERMENTAL

Ethyl diphenyloxamate (II). A mixture of 5.07 g (0.03 mole) of diphenylamine (I) and 5.5 g (0.04) mole of ethyl chloroglyoxylate was heated on the water bath until solution of diphenylamine and removal of hydrogen chloride was complete. The cooled reaction mass was poured into 50 ml of water, and the heavy oil obtained here became crystalline when stirred. Yield 76.6 g (94.2%). Plates (from alcohol) with m.p. 86-87°. Literature: m.p. 87° [3].

Benzilic acid diphenylamide (III). To the phenylmagnesium bromide, obtained from 18.8 g (0.12 mole) of bromobenzene and 2.8 g of magnesium in 50 ml of ether, was added a solution of 8.07 g (0.03 mole) of (II) in 20 ml of ether. The reaction mass was decomposed with 10% hydrochloric acid, and the reaction product was isolated as had been described earlier [1]. Difficultly soluble in benzine, and readily soluble in other organic solvents. With concentrated sulfuric acid an acetic acid solution of the compound gives a rapidly vanishing brown color. Yield 7.1 g (61.3%). Plates (from alcohol) with m.p. 103-105°.

Found %: N 3.86, 3.54. $C_{26}H_{21}O_2N$. Calculated %: N 3.69.

p-Tolylic acid diphenylamide (IV). Starting substances: 5.4 g (0.02 mole) of (II), 12.0 g (0.07 mole) of p-bromotoluene, 1.61 g (0.07 mole) of magnesium. The organomagnesium complex was decomposed with a saturated solution of ammonium chloride. With concentrated sulfuric acid the compound gives a rapidly vanishing brown color. Yield 3.2 g (40%). Slowly crystallizes from alcohol as colorless rhombic crystals with m.p. 111-112°.

Found %: N 3.28, 3.30. $C_{28}H_{25}O_2N$. Calculated %: N 3.43.

4,4'-Dimethoxybenzilic acid diphenylamide (V). For reaction we took 16.4 g (0.07 mole) of p-iodoanisole, 1.61 g (0.07 mole) of magnesium and 5.4 g (0.02 mole) of (II). The reaction mass was decomposed with a saturated solution of ammonium chloride. Readily soluble in the ordinary organic solvents. With concentrated sulfuric acid the compound gives a vanishing red-violet color. Yield 4.5 g (51%). Needles (from alcohol) with m.p. 108-109°.

Found %: 3.08, 3.19. $C_{28}H_{25}O_4N$. Calculated %: N 3.18.

2,2'-Dimethoxybenzilic acid diphenylamide (VI). The organomagnesium complex, obtained from 5.4 g (0.02 mole) of (IV), 9.36 g (0.04 mole) of o-iodoanisole and 9.7 g (0.04 mole) of magnesium, was decomposed with 10% hydrochloric acid solution. The product is soluble in most organic solvents. With concentrated sulfuric acid it gives a rapidly vanishing green color. Yield 6.2 g (70.5%). Plates (from alcohol) with m.p. 129-130°.

Found %: N 2.94, 3.16. $C_{28}H_{25}O_4N$. Calculated %: N 3.18.

1,3,3- Triphenyloxindole (VII). The experiments were run by the earlier described method [4]. For the reaction we took 5 g of substance (III) in 15 ml of glacial acetic acid and 15 ml of concentrated sulfuric acid. Yield 4.3 g (93%). Prisms (from glacial acetic acid) with m.p. 160-162°. Literature: m.p. 161° [2].

1-Phenyl-3,3-di-(p-tolyl)-oxindole (VIII). a) We took 1 g of (IV) in 10 ml of glacial acetic acid and 5 ml of concentrated sulfuric acid. Yield 0.55 g (57.5%).

b) The organomagnesium complex, obtained from 6.7 g (0.025 mole) of (II), 21.8 g (0.1 mole) of p-iodotoluene and 2.4 g (0.1 mole) of magnesium, was decomposed with 10% hydrochloric acid. The obtained precipitate was worked up in the usual manner. Difficultly soluble in alcohol and benzine, and more readily soluble in acetic acid. Yield 3.1 g (31.8%). Octahedral crystals (from glacial acetic acid) with m.p. 196-197°.

Found %: N 3.41, 3.21, $C_{28}H_{23}ON$. Calculated %: N 3.59.

1-Phenyl-3,3-di-(p-anisyl)-oxindole (IX). a) Obtained by the addition of 0.5 ml of concentrated sulfuric acid 0.5 g of (V) in 5 ml of glacial acetic acid. Yield 0.4 g (83%).

b) Starting substances: 5.4 g (0.02 mole) of (II), 9.3 g (0.04 mole) of p-iodoanisole and 0.97 g (0.04 mole) of magnesium. The decomposition was made with 10% hydrochloric acid. Readily soluble in benzine, toluene and chloroform, and difficultly soluble in alcohol. Yield 5.3 g (65%). Rhombic crystals (from alcohol) with m.p. 165-166°.

Found %: N 3.18, 3.33. $C_{28}H_{23}O_3N$. Calculated %: N 3.32.

1-Phenyl-3,3-di-(o-anisyl)-oxindole (X). For the reaction we took 2 g of (VI) in 10 ml of glacial acetic acid and 5 ml of concentrated sulfuric acid. Difficultly soluble in alcohol and readily soluble in other organic solvents. Crystals (from alcohol) with m.p. 173-174°.

Found %: N 3.37. $C_{28}H_{23}O_3N$. Calculated %: N 3.32.

SUMMARY

1. A method was developed for the preparation of N-phenyl derivatives of 3,3-diaryloxindoles; here a number of previously unknown compounds were obtained and their properties studied.

2. It was established that the oxindole ring is closed more easily in the diphenylamides than in the anilides of the same diarylglycolic acids. A hypothetical explanation of this experimental fact is that it is due to an increase in the number of nucleophilic reaction centers.

3. A number of diphenylamides of the diarylglycolic acids were prepared and their properties studied.

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Bz-ISOQUINOLINECARBOXALDEHYDES

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Aldehydes of the isoquinoline series have received comparatively little study up to now. Of the eight possible formylisoquinolines only three aldehydes with the formyl group in the pyridine ring have been described [1, 2]. However, up to now not a single aldehyde with the formyl group in the benzene ring of the isoquinoline nucleus has been described.

The synthesis of the 5- and 7-formylisoquinolines and of 7-formyl-1-phenylisoquinoline is reported in this paper. The aldehydes were obtained by heating the 5-, 7- and 7-methyl-1-phenylisoquinolines, taken as the free bases, with SeO_2. A stormy reaction begins at 150-180° and the temperature spontaneously rises above 200°. The products of the reaction are metallic selenium and the corresponding formylisoquinoline. The obtained aldehydes were characterized by their conversion to the 2,4-dinitrophenylhydrazones and the semicarbazones (table)..

Constants of Bz-Isoquinolinecarboxaldehydes

Aldehyde	Yield (in %)	Melting point		
		aldehyde	semicarbazones	2,4-dinitrophenylhydrazone
7-Formyl-1-phenylisoquinoline	78	84-85°	273-275°	above 300°
7-Formylisoquinoline	75	103-104	253-254	272-273
5-Formylisoquinoline	72	85-86	259-260	241-242

To obtain 7-formylisoquinoline and 7-formyl-1-phenylisoquinoline the following condensations were run: 1) with malonic acid by the Knoevnagel reaction to yield β-7-isoquinolylacrylic acid and tolyl β-(1-phenyl-7-isoquinolyl)-acrylic acid, respectively; 2) with nitromethane in the presence of dimethylaniline to yield α-nitro-β-hydroxy-β-(7-isoquinolyl)-ethane and α-nitro-β-hydroxy-β-(1-phenyl-7-isoquinolyl)-ethane, respectively; 3) with acetone in the presence of sodium hydroxide to yield 1,5-di-(7-isoquinolyl)-1,4-pentadien-3-one and 1,5-di-(1-phenyl-7-isoquinolyl)-1,4-pentadien-3-one, respectively.

For the oxidation we developed methods for obtaining the necessary methylisoquinolines. 7-Methyl-1-phenylisoquinoline was obtained from ω-amino-p-methylacetophenone by its cyclization to N-[β-hydroxy-β-(p-tolyl)-ethyl]-benzamide, and also from N-benzoyl-β-(p-tolyl)-ethylamine through 7-methyl-1-phenyl-3,4-dihydroisoquinoline, which was dehydrogenated by heating with skeletal nickel. The needed β-(p-tolyl)-ethylamine was obtained by the Friedel-Crafts type of reaction, i.e. by the heating of a solution of N-(β-chloroethyl)-benzamide in excess toluene with anhydrous $AlCl_3$, followed by acid hydrolysis of the reaction product [3].

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*Deceased

$$CH_3C_6H_5 + ClCH_2CH_2NHCOC_6H_5 \xrightarrow{AlCl_3} p\text{-}CH_3C_6H_4CH_2CH_2NHCOC_6H_5 \xrightarrow{H_2SO_4}$$
$$\longrightarrow p\text{-}CH_3C_6H_4CH_2CH_2NH_2.$$

The starting N-(β-chloroethyl)-benzamide was obtained by the benzoylation of ethanolamine with ethyl benzoate and subsequent treatment of the N-benzoylethanolamine with phosphorus trichloride.

7-Methylisoquinoline had been obtained earlier [4] by the rearrangement of the ethyl ester of m-methylphthalimidoacetic acid and subsequent transformation of the obtained 3-carboethoxy-4-hydroxy-7-methylisocarbostyril into isoquinoline. We obtained 7-methylisoquinoline by the reduction of the formyl derivative of ω-amino-p-methylacetophenone and subsequent cyclization of the obtained N-(β-hydroxy-β-p-tolylethyl)-formamide. 5-Methylisoquinoline was described as the picrate. The cyclization of N-[β-(o-tolyl)-ethyl]-formamide by boiling in tetralin with P_2O_5 gave 5-methyl-3,4-dihydroisoquinoline in 34% yield [5]. By using xylene as the solvent a a mixture of P_2O_5 and PCl_3 [6] we were able to obtain 5-methyl-3,4-dihydroisoquinoline in 51% yield. Instead of palladium black we used skeletal nickel for the dehydrogenation. In addition, we also obtained 5-methylisoquinoline by the cyclization of the formyl derivative of β-methoxy-β-(o-tolyl)-ethylamine. Mannich and Walther [7] expressed the theory that the cyclization of acylated β-methoxy-β-arylethylamines by the method of Pictet and Gams is not suitable for obtaining isoquinolines with hydroxy or alkoxy groups in the nucleus. However, under our conditions N-[β-methoxy-β-(o-tolyl)-ethyl]-formamide gave 5-methylisoquinoline in 18% yield.

The synthesis of β-methoxy-β-(o-tolyl)-ethylamine was accomplished by the following scheme

$$o\text{-}CH_3C_6H_4CH{=}CHNO_2 + CH_3OH \longrightarrow$$
$$\rightarrow o\text{-}CH_3C_6H_4CH(OCH_3)CH_2NO_2 \longrightarrow$$
$$\rightarrow o\text{-}CH_3C_6H_4CH(OCH_3)CH_2NH_2.$$

For the reduction of β-methoxy-β-aryl-α-nitroethane we used freshly copper-plated zinc dust and formic acid [7, 8].

EXPERIMENTAL

1. **ω-Amino-p-methylacetophenone hydrochloride** was obtained by the method of [9]. To obtain the yield indicated by the authors it was necessary to thoroughly grind the addition product of hexamethylenetetramine with ω-bromo-p-methylacetophenone, shake vigorously with water at 37-38°, suction-filter rapidly from undissolved residue, and immediately pass a strong stream of SO_2 through the filtrate.

2. **ω-Benxylamino-p-methylacetophenone.** In a 2-liter flask was placed 15.8 g (0.0855 mole) of ω-amino-p-methylacetophenone hydrochloride and 20.5 g of finely ground $NaHCO_3$, and then a solution of 15 ml (0.13 mole) of benzoyl chloride in 35 ml of ether was added. The mixture was heated until reaction began (foaming), then kept for 2 days at room temperature, after which a solution of 5 ml (0.04 mole) of benzoyl chloride in 15 ml of ether was added, and the whole boiled for a short time. The cooled reaction mixture was filtered, the solidified oily layer ground in a mortar, and then treated with an excess of dilute NaOH solution. The dried product was recrystallized from alcohol. Yield 19.5 g (90%). M.p. 118-119°, which agrees with the literature [10].

3. **1-p-Tolyl-2-benzoylamino-1-ethanol.** A solution of13.3 g (0.0645 mole) of ω-benzoylamino-p-methylacetophenone in 160 ml of alcohol, containing traces of phenolphthalein, was reduced at 40° with 148 g of 3% sodium amalgam, maintaining either a neutral or weakly acid reaction by the addition of glacial acetic acid. Toward the end of the reduction the temperature was allowed to rise to 50°. After separating the mercury the reaction mass was poured into 1 liter of water; the curdy precipitate was dried at 60° and then recrystallized from alcohol. Yield 12 g (73%). White mother-of-pearl plates, m.p. 175-176°; extremely soluble in benzene.

Found %: C 75.60, 75.52; H 6.84, 6.69; N 5.55, 5.48. $C_{16}H_{17}O_2N$. Calculated %: C 75.30; H 6.67; N 5.49.

4. 7-Methyl-1-phenylisoquinoline was obtained from 1-p-tolyl-2-benzoylamino-1-ethanol by boiling with a mixture of P_2O_5 + $POCl_3$, in xylene [6]. Passage of dry hydrogen chloride through the benzene extract, followed by removal of the benzene in vacuo, gave an oily hydrochloride. Yield 4.6 g, 90%. Vacuum-heating of the hydrochloride for 2 hours at 120°, after the complete removal of traces of hydrogen chloride, gave the hydrochloride as a hygroscopic glassy mass. Solution in the minimum amount of alcohol and the addition of an excess of absolute ether gave a crystalline hydrochloride, m.p. 146-148°. For analysis the product was precipitated twice with absolute ether from anhydrous alcohol, m.p. 150.2-150.8°.

Found %: N 5.75, 5.48. $C_{16}H_{14}NCl$. Calculated %: N 5.48.

A solution of the purified hydrochloride in distilled water was made alkaline with 20% sodium hydroxide solution and then extracted with benzene. Vacuum-evaporation of the benzene gave the free base. Clear oil, which crystallized after long standing in a desiccator, m.p. 103-104°.

Found %: N 6.30, 6.62. $C_{16}H_{13}N$. Calculated %: N 6.38.

After two recrystallizations from alcohol the picrate of the base had m.p. 178.5-179.2°.

Found %: N 12.76, 12.83. $C_{22}H_{16}O_7N_4$. Calculated %: N 12.53.

5. ω-Formylamino-p-methylacetophenone. A mixture of 10 g of ω-amino-p-methylacetophenone hydrochloride, 6 g of sodium formate and 5 ml of 85% formic acid was heated for 30 minutes under reflux in an oil bath at 135°, poured into 400 ml of water, boiled for 2-3 minutes with charcoal, and the hot solution filtered, using a slight suction. Yield 5.6 g (59%). After two recrystallizations from water, m.p. 88-89°.

Found %: N 8.07, 8.01. $C_{10}H_{11}O_2N$. Calculated %: N 7.91.

6. 1-p-Tolyl-2-formylamino-1-ethanol. a) A solution of 10 g of ω-formylamino-p-methylacetophenone in 150 ml of 99% alcohol, containing traces of phenolphthalein, was reduced with 135 g of 2% sodium amalgam under the above described conditions. After removing the mercury and some of the sodium acetate the mixture was evaporated to ~30 ml, about 100 ml of dry benzene was added, and again the mixture was filtered from sodium acetate. The benzene solution was dried over Na_2SO_4, the benzene distilled off, and the residue vacuum-distilled. Yield 6 g (59.8%) B.p. 175-180° (3 mm).

Found %: C 67.21, 67.13; H 7.38, 7.40; N 7.91, 8.02. $C_{10}H_{13}O_2N$. Calculated %: C 67.03; H 7.26; N 7.82.

b) 8.8 g of ω-formylamino-p-methylacetophenone was reduced with aluminum isopropoxide (from 1.5 g of aluminum shavings) [11]. The benzene extracts were dried over Na_2SO_4; the residue after distilling off the benzene was vacuum-distilled. Yield 6.9 g (78%). B.p. 172-176° at 2.5 mm.

7. 7-Methylisoquinoline was obtained from 1-p-totyl-2-formyl-amino-1-ethanol by the method of [9]. The yield of oily hydrochloride was 26.6%. The hydrochloride was obtained crystalline by the vacuum-heating of the oily product for 2 hours at 120°. After repeated recrystallization from a mixture of isopropyl alcohol, ligroin and absolute ether (2 : 2 : 1 by volume), m.p. 185-186°.

Found %: N 7.78, 7.80. $C_{10}H_{10}NCl$. Calculated %: N 7.80.

The free base was obtained from the hydrochloride as described above. After standing for several days in a desiccator the transparent oil crystallized. The free base had m.p. 67-68°. According to [4], m.p. 66°.

The picrate after two recrystallizations from alcohol had m.p. 197-198°, which agrees with the data of [4].

8. N-Benzoylethanolamine. A mixture of 60 ml of freshly distilled ethanolamine and 140 ml of ethyl benzoate was heated in a Favorsky flask (with a dephlegmator 25 cm high) in such a manner that the reaction alcohol slowly distilled (5-6 drops a minute). After distilling off 54 ml of alcohol the residue was placed in a desiccator over sulfuric acid. After 3 weeks the product had completely solidified to a crystalline mass. M.P. 57-58°, which is in agreement with the data of [12].

9. N-(β-Chloroethyl)-benzamide. In a three-necked flask, fitted with dropping funnel, reflux condenser and mechanical stirrer with a mercury seal, was placed 20.6 g of N-benzoylethanolamine and 30 ml of dry benzene. With vigorous stirring and heating on the water bath a solution of 6.15 g of PCl_3 in 100 ml of dry benzene was added in drops, and the whole boiled for 30 minutes. After cooling the benzene layer was decanted from the nearly solid residue, and washed with water. The residue after distilling off the benzene was recrystallized from the minimum amount of benzene. M.p. 104-105°, which agrees with the literature [13].

10. N-Benzoyl-2-(p-tolyl)-ethylamine. A mixture of 17.25 g of N-(β-chloroethyl)-benzamide, 100 ml of dry toluene and 23 g of anhydrous $AlCl_3$ was heated for 6 hours on the boiling bath, with protection from moisture. The mixture was decomposed with ice and concentrated hydrochloric acid. The toluene layer was successively washed with water, dilute soda solution, and water. The toluene was steam-distilled; the residual viscous mass was hydrolyzed by boiling for 6 hours with 100 ml of 30% sulfuric acid, made alkaline with 20% NaOH solution, and then the reaction mass was distilled with superheated steam, collecting the distillate in dilute hydrochloric acid solution. The solution was evaporated to dryness, the residue washed with ether, dissolved in a small amount of alcohol, and then precipitated by the addition of an excess of dry ether. The obtained 2-(p-tolyl)-ethylamine hydrochloride was dissolved in 20 ml of water, a solution of 1 g of sodium hydroxide in 4 ml of water was added, and then 5.5 ml of benzoyl chloride was slowly added with stirring. After reaction was ended the mixture was boiled for 2-3 min. to decompose the excess benzoyl chloride, followed by extraction with ether, removal of the ether by distillation, and recrystallization of the residue from alcohol. Based on N-(β-chloroethyl)-benzamide the yield of N-benzoyl-2-(p-tolyl)-ethylamine was 39.5% (8.9 g). M.p. 88-89°. According to [14]: m.p. 89°.

11. 7-Methyl-1-phenyl-3,4-dihydroisoquinoline was obtained from N-benzoyl-2-(p-toyl)-ethylamine by the method of [9]. The combined benzene extracts were dried over $MgSO_4$, and after distilling off the benzene the free base was vacuum-distilled. Yield 91.5%. B.p. 147-150° (6 mm); colorless oil, which solidified to a crystalline mass with m.p. 78-79°.

Found %: N 6.41, 6.46. $C_{16}H_{15}N$. Calculated %: N 6.32.

The picrate after two recrystalizations from alcohol had m.p. 183.5-184°.

Found %: N 12.32, 12.40. $C_{22}H_{18}O_7N_4$. Calculated %: N 12.42.

The passage of HCl gas through a solution of the free base in dry benzene gave the hydrochloride. The obtained oil readily crystallized when rubbed with a glass rod. After precipitation from anhydrous alcohol with absolute ether the hydrochloride had m.p. 218-219°.

Found %: N 5.75, 5.48. $C_{16}H_{16}NCl$. Calculated %: N 5.46.

12. 7-Methyl-1-phenylisoquinoline. Two grams of 7-methy-1-phenyl-3,4-dihydroisoquinoline was heated for 5 hours with 3 small spoonfuls of freshly prepared skeletal nickel catalyst. The cooled reaction mixture was extracted with benzene and filtered from the catalyst; removal of the benzene gave the free base with m.p. 103-104°. After three recrystallizations from alcohol the picrate had m.p. 178-179°. Its mixture with the picrate of the above obtained 7-methyl-1-phenylisoquinoline showed no melting point depression. The hydrochloride had m.p. 150.2-150.8°.

13. β-o-Tolylpropionamide. To 30 g of β-o-tolylpropionic acid was added 14 ml of $SOCl_2$ and, after removing the excess $SOCl_2$ in vacuo, the acid chloride without further purification was used to obtain the amide. For this the obtained acid chloride was added with good mechanical stirring to 100 ml of 30% ammonia at −5%. The amide was immediately filtered and recrystallized from water. Yield 28.5 g (95%). M.p. 110-111°.

Found %: N 8.63, 8.49. $C_{10}H_{13}ON$. Calculated %: N 8.59.

14. β-o-Tolylethylamine was obtained from β-o-tolylpropionamide by treatment with sodium hypobromite in accord with [15]. The hydrochloride of β-o-tolylethylamine had m.p. 225-226° [16]. Yield 94%.

15. 5-Methyl-3,4-dihydroisoquinoline was obtained from N-formyl-β-o-tolylamine [6]. The combined ether extracts were dried over $MgSO_4$. After removal of the benzene and drying in vacuo the free base was obtained as an oil. Yield 51.8%.

Found %: N 9.82, 9.90. $C_{10}H_{11}N$. Calculated %: N 9.69.

After two recrystallizations from alcohol the picrate melted at 182-183°, which agrees with the data of [5].

The hydrochloride, obtained by passing dry HCl gas through a benzene solution of the free base, was precipitated twice from anhydrous alcohol with absolute ether. M.p. 228-229°.

Found %: N 8.01, 7.86. $C_{10}H_{12}NCl$. Calculated %: N 7.72.

16. 5-Methylisoquinoline was obtained from 1.6 g of 5-methyl-3,4-dihydroisoquinoline with skeletal nickel under the above described conditions. Yield 1.3 g (82%).

After two recrystallizations from alcohol the picrate melted at 235-236°, in accord with the data of [5].

17. 1-Methyl-2-(α-methoxy-β-nitroethyl)-benzene. To 200 ml of anhydrous methanol was added 10 g of finely divided o-methyl-ω-nitrostyrene, and then gradually, with ice-cooling, a solution of sodium methylate, prepared from 4.6 g of sodium and 100 ml of anhydrous methanol. The reaction mixture was shaken for 10 minutes and then immediately acidified with 122 g of glacial acetic acid. The methanol was removed in vacuo, the residue treated with water, extracted with ether, and the extract dried over Na_2SO_4. After distilling off the ether the residue was vacuum-distilled. Yield 9.12 g (76%). B.p. 127-129° (12 mm).

18. β-o-Tolyl-β-methoxyethylamine. To a solution of 17.55 g of o-methyl-α-methoxy-β-nitroethylbenzene in 100 ml of 85% formic acid was gradually added with stirring and cooling 20 g of freshly copper-plated zinc dust, and the whole heated for 15 minutes on the water bath. After letting stand for several hours the zinc dust was filtered, the precipitate successively washed with formic acid and methyl alcohol, and the combined filtrates evaporated in vacuo. The residue was treated with 100 ml of water and then extracted with ether. The water layer was treated with 20% sodium hydroxide solution until it showed strongly alkaline. The free base was extracted with ether, and the ether extract was dried over $MgSO_4$. The product was vacuum-distilled, collecting the fraction with b.p. 113-115° (12 mm). Yield 5.35 g (36%). Passage of a stream of dry HCl gas through an ether solution of the free base gave the hydrochloride. M.p. 153-154°.

Found %: N 7.23, 7.15. $C_{10}H_{16}ONCl$. Calculated %: N 6.98.

19. N-Formyl-β-o-tolyl-β-methoxyethylamine. A mixture of 10 g of β-o-tolyl-β-methoxyethylamine hydrochloride, 6 g of HCOONa and 5 ml of 85% HCOOH was heated for 4 hours in an oil bath at 160°. After cooling the mixture was extracted several times with hot benzene. The extract was washed with water. The product (8.7 g) was dried by azeotropic distillation with repeated addition of small amounts of benzene, and without further purification was subjected to cyclization.

20. 5-Methylisoquinoline was obtained from N-formyl-β-o-tolyl-β-methoxyethylamine by cyclization under the conditions used [6] to cyclize acylated β-hydroxy-β-arylethylamines (boiling for 5 hours). The benzene extracts were dried over $MgSO_4$, the benzene removed by distillation, and the residue dried on the water bath. The yield of the free base was 18%. After standing in a desiccator for three weeks the oily free base deposited some crystals, which after drying on porous plate melted at 47-48°.

Found %: N 9.98, 10.1. $C_{10}H_9N$. Calculated %: N 9.81.

The passage of dry HCl gas through a benzene solution of the free base gave the hydrochloride, which solidified after heating in vacuo for 2 hours at 120°. After two recrystallizations from a mixture of isopropyl alcohol, ligroin nd absolute ether (2:2:1) the m.p. was 187-189°.

Found %: N 8.02, 7.94. $C_{10}H_{10}NCl$. Calculated %: N 7.81.

After recrystallization from alcohol the picrate melted at 235-236° and did not depress the melting point when mixed with the picrate of the earlier obtained 5-methylisoquinoline.

21. Bz-Formylisoquinolines. A mixture of 0.01 mole of the methylisoquinoline and 1.25 g (0.011 mole) of selenium dioxide was cautiously heated with a free flame. A stormy reaction began at 140-180°; after removing the flame the temperature spontaneeously rose to 180-200°. As soon as the temperature of the reaction mixture began to drop the reaction mass was again heated for several minutes at 210°. After cooling the mixture was extracted with ether, filtered from metallic selenium, the ether removed by distillation, and the residue

recrystallized from water. The constants of the obtained aldehydes and of some of their derivatives are given in the Table.

The semicarbazones were obtained in aqueous alcohol medium from the aldehyde, semicarbazide hydrochloride and anhydrous CH_3COONa. The substances were purified by recrystallization from a large volume of alcohol. The 2,4-dinitrophenylhydrazones were obtained from the aldehydes and a saturated solution of 2,4-dinitrophenylhydrazine in anhydrous alcohol. Below we give the analysis data for the compounds reported in the Table.

7-Formylisoquinoline. Found %: C 76.49, 76.64; H 4.50, 4.61; N 9.12, 9.23. $C_{10}H_7ON$. Calculated %: C 76.43; H 4.46; N 8.92.

Semicarbazone. Found %: N 26.30, 26.43. $C_{11}H_{10}ON_4$. Calculated %: N 26.17.

2,4-Dinitrophenylhydrazone. Found %: N 21.04, 20.94. $C_{16}H_{11}O_4N_5$. Calculated %: N 20.75.

5-Formylisoquinoline. Found %: C 76.42, 76.50; H 4.61, 4.55; N 9.18, 9.05. $C_{10}H_7ON$. Calculated %: C 76.43; H 4.46; N 8.92.

Semicarbazone. Found %: N 26.28, 26.44. $C_{11}H_{10}ON_4$. Calculated %: N 26.17.

2,4-Dinitrophenylhydrazone. Found %: N 21.03, 20.93. $C_{16}H_{11}O_4N_5$. Calculated %: N 20.75.

7-Formyl-1-phenylisoquinoline. Found %: C 82.40, 82.51; H 4.84, 4.91; N 6.28, 6.12. $C_{16}H_{11}ON$. Calculated %: C 82.41; H 4.74; N 6.02.

Semicarbazone. Found %: N 19.52, 19.40. $C_{17}H_{14}ON_4$. Calculated %: N 19.31.

2,4-Dinitrophenylhydrazone. Found %: N 16.81, 16.98. $C_{22}H_{15}O_4N_5$. Calculated %: N 16.96.

22. 7-Isoquinolylacrylic acid. To a solution of 0.28 g (0.002 mole) of 7-formylisoquinoline and 0.2 g (0.002 mole) of malonic acid in 2 ml of alcohol was added a drop of piperidine, and the mixture was heated underreflux for 2 hours. The substance was recrystallized from alcohol. Yield 0.28 g (72%). M.p. 237-238°.

Found %: N 7.25, 7.14. $C_{12}H_9O_2N$. Calculated %: N 7.05.

23. (1-Phenyl-7-isoquinolyl)-acrylic acid was obtained from 7-formyl-1-phenylisoquinoline in the same manner as the preceeding compound. Yield 71.5%. Recrystallized from a large volume of dilute alcohol. M.p. 283-285° (with decomposition).

Found %: N 5.26, 5.35. $C_{18}H_{13}O_2N$. Calculated %: N 5.09.

24. α-Nitro-β-hydroxy-β-(7-isoquinolyl)-ethane. To a mixture of 0.3 g (0.005 mole) of nitromethane and 0.32 g (0.0023 mole) of 7-formylisoquinoline was added 2 drops of dimethylaniline. The reaction mixture evolved heat; it was cooled and kept for 2 hours at room temperature. The addition of 3 ml of water and rubbing with a rod caused the oil to crystallize, after which the product was pressed on a porous plate. Yield 0.2 g (55%). M.p. 116-117° (from aqueous alcohol).

Found %: N 12.52, 12.48. $C_{11}H_{10}O_3N_2$. Calculated %: N 12.84.

25. α-Nitro-β-hydroxy-β-(1-phenyl-7-isoquinolyl)-ethane was obtained from 7-formyl-1-phenylisoquinoline in the same manner as the preceding compound (kept overnight). Yield 68%. M.p. 132° (from alcohol).

Found %: N 9.74, 9.81. $C_{17}H_{14}O_3N_2$. Calculated %: N 9.55.

26. 1,5-Di-(7-isoquinolyl)-1,4-pentadien-3-one. To a solution of 0.32 g (0.0023 mole) of 7-formylisoquinoline and 2 ml of alcohol was added from a microburette 3 drops (0.0012 mole) of acetone and 0.2 ml of 5 N NaOH. The mixture was kept for 2 hours at room temperature, after which the appearance of the first crystals of the condensation product was observed. Rubbing with a glass rod caused the main portion of the product to crystallize. Yield 0.23 g (58%). M.p. 127-129° (from anhydrous alcohol).

Found %: N 8.46, 8.55. $C_{23}H_{16}ON_2$. Calculated %: N 8.35.

27. 1,5-Di-(1-phenyl-7-isoquinolyl)-1,4-pentadien-3-one was obtained from 7-formyl-1-phenylisoquinoline in the same manner as the preceding compound (kept overnight). Yield 60%. M.p. 183-184° (from anhydrous alcohol).

Found %: N 5.81, 5.93. $C_{35}H_{24}ON_2$. Calculated %: N 5.72.

SUMMARY

The oxidation of the 5- and 7-methylisoquinolines and of 7-methyl-1-phenylisoquinoline gave the 5- and 7-formylisoquinoline and 7-formyl-1-phenylisoquinoline. The obtained formylisoquinolines were characterized by their conversion into the 2,4-dinitrophenylhydrazones and semicarbazones.

The condensation reactions of 7-formylisoquinoline and 7-formyl-1-phenylisoquinoline with malonic acid, acetone and nitromethane were studied.

The cyclization of the N-benzoyl and N-formyl derivative of β-hydroxy-β-(p-tolyl)-ethylamine in the presence of a mixture of phosphorus oxychloride and phosphorus pentoxide gave 7-methyl-1-phenylisoquinoline and 7-methylisoquinoline, respectively. The cyclization of N-benzoyl-(p-tolyl)-ethylamine gave 7-methyl-1-phenyl-3,4-dihydroisoquinoline.

It was established that the reaction of toluene with N-benzoyl-β-chloroethylamine in the presence of anhydrous $AlCl_3$ yields N-benzoyl-β-p-tolylethylamine. This reaction is a convenient method for the preparation of β-p-tolylethylamine.

The cyclization of β-methoxy-β-(o-tolyl)-ethylamine in the presence of a mixture of phosphorus oxychloride and phosphorus pentoxide yields 5-methylisoquinoline.

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SARKOMYCIN AND ITS ANALOGS

I. SYNTHESIS OF DIHYDROSARKOMYCIN AND ITS ANTIPODE

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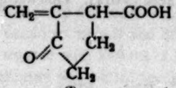
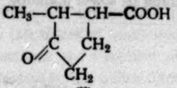
In 1954 the Japanese investigators [1] described a new, very interesting antibiotic—sarkomycin, showing not only antibacterial but also antitumor activity. The structure of this antibiotic was elucidated at the end of 1955 by a group of American investigators [2], who established that sarkomycin is 2-methylene-3-cyclopentanonecarboxylic acid (I). At the same time it was shown by the American investigators that the reduction product of sarkomycin, namely dihydrosarkomycin and proving to be (+)-2-methyl-3-cyclopentanonecarboxylic acid (II), shows the same antitumor activity as the antibiotic itself.


(I)


(II)

The substantial antitumor activity shown by sarkomycin and dihydrosarkomycin attracted our attention, and consequently as early as the end of 1955 we began to search for different methods of synthesizing the antibiotic itself, and also its various analogs, with the purpose in mind of studying the relationship between structure and antitumor action in this group of compounds. The first results of our studies, dealing with the methods for the synthesis of dihydrosarkomycin and its (−)-antipode, are described in the present communication.

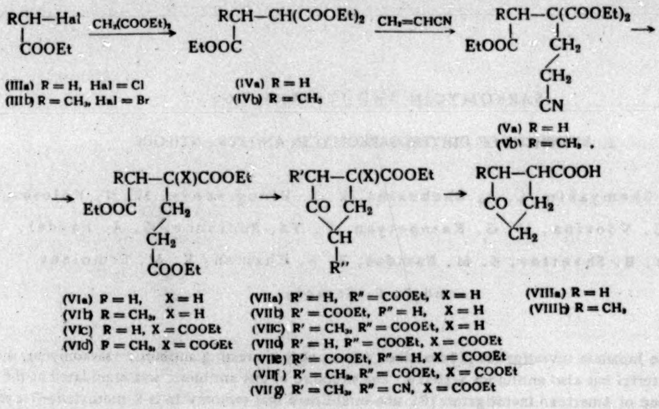
Although the synthesis of sarkomycin and dihydrosarkomycin has not been described in the literature up to now, still the racemic 2-methyl-3-cyclopentanonecarboxylic acid was first synthesized as early as 1908 [3], and recently an excellent preparative method for obtaining the ester of this acid was described in detail [4].

We investigated and developed a new and simple method for the synthesis of racemic 2-methyl-3-cyclopentanonecarboxylic acid (VIIIb), accomplished by the following scheme

$$(\mathrm{IIIb}) \xrightarrow{80\%} (\mathrm{IVb}) \xrightarrow{80\%} (\mathrm{Vb}) \xrightarrow{85\%} (\mathrm{VIb}) \xrightarrow[\mathrm{EtONa}(85\%)]{\mathrm{Na}(88\%)} (\mathrm{VIIc}) \xrightarrow{85\%} (\mathrm{VIIIb})$$

The intermediate compound (Vb) can be converted into (VId) in 86% yield, and then into (VIIf) in 90%

yield,* but the hydrolysis and decarboxylation of the latter compound to (VIIIb) does not proceed too well, as a result of which this method of obtaining the racemic acid (VIIIb) is less practical than the method given above. For the same reason it proved inexpedient to effect the transformation of (Vb) into (VIIIb) through (VIIg).



(IIIa) R = H, Hal = Cl
(IIIb) R = CH$_3$, Hal = Br

(IVa) R = H
(IVb) R = CH$_3$

(Va) R = H
(Vb) R = CH$_3$.

(VIa) R = H, X = H
(VIb) R = CH$_3$, X = H
(VIc) R = H, X = COOEt
(VId) R = CH$_3$, X = COOEt

(VIIa) R' = H, R" = COOEt, X = H
(VIIb) R' = COOEt, R" = H, X = H
(VIIc) R' = CH$_3$, R" = COOEt, X = H
(VIId) R' = H, R" = COOEt, X = COOEt
(VIIe) R' = COOEt, R" = H, X = COOEt
(VIIf) R' = CH$_3$, R" = COOEt, X = COOEt
(VIIg) R' = CH$_3$, R" = CN, X = COOEt

(VIIIa) R = H
(VIIIb) R = CH$_3$

The method developed by us for the synthesis of racemic 2-methyl-3-cyclopentanonecarboxylic acid (VIIIb) is also fully suitable for obtaining its lower homolog—acid (VIIIa). This compound was obtained by the following scheme

$$\begin{tikzcd}
 & & & (VIa) \arrow[r, "78\%"] & (VIIa + VIIb) \arrow[dr, "85\%"] & \\
(IIIa) \arrow[r, "58\%"] & (IVa) \arrow[r, "95\%"] & (Va) \arrow[ur, "90\%"] \arrow[dr, "82\%"'] & & & (VIIIa) \\
 & & & (VIc) \arrow[r, "68\%"] & (VIId + VIIa) \arrow[ur, "80\%"'] &
\end{tikzcd}$$

As regards the final step in the synthesis of dihydrosarkomycin—the separation of racemic 2-methyl-3-cyclopentanonecarboxylic acid into its antipodes, we were able to accomplish this with the aid of brucine. Heating of the latter in ethyl acetate with the racemic acid gave a mixture of well-crystallized diastereoisomeric salts, which could then be easily separated by fractional crystallization from ethyl acetate.** It is important that the less soluble brucine salt of dihydrosarkomycin deposit from this solvent first, the yield of which reaches 80%; the brucine salt of the antipode of dihydrosarkomycin can be isolated in 60% yield. The decomposition of the brucine salts with 5% soda solution gave dihydrosarkomycin and its antipode in an optically pure state. From the melting point and the specific rotation the dihydrosarkomycin synthesized in this manner proved identical with the hydrogenation product of the natural antibiotic (see [2]).

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* It should be mentioned that the cyclization of (VId) to (VIIf) proceeds much better under the influence of EtONa than under the influence of Na; in the first case the yield is 90%, and in the second it is only 70%.

** It should be mentioned that if strychnine is used, and also either L- or D-threo-1-(p-nitrophenyl)-2-amino-1,3-propanediol, the mixture of salts deposits as a noncrystallizing oil.

To study the antitumor activity, dihydrosarkomycin and its antipode were converted to the calcium salts, which proved to be more suitable for biological testing than the free acids. According to the data of M. M. Maevsky (Institute of Experimental Cancer Pathology and Therapy of the Academy of Medical Sciences of the USSR), only dihydrosarkomycin shows antitumor activity, while its antipode proved to be practically inactive (when treated on mice with Ehrlich carcinoma, inoculated subcutaneously).

EXPERIMENTAL

1. Preparation of triethyl 1,1,2-propanetricarboxylate (IVb). To the sodiomalonic ester, obtained from 1000 g (6.25 moles) of malonic ester and 144 g (6.25 g-at.) of sodium in 2 liters of anhydrous alcohol, was added in one hour at 50-55° and with stirring 1086 g (6.00 moles) of ethyl α-bromopropionate. The reacting mixture was boiled for 30 minutes, the alcohol was distilled off, and the residue was worked up in the usual manner. The yield of triethyl propanetricarboxylate was 1250 g (80%), b.p. 99-101° (1 mm), n_D^{18} 1.4310.

2. Preparation of triethyl 1-cyano-3,3,4-pentanetricarboxylate (Vb). To a solution of 1300 g (5.00 moles) of triester (IVb) and 3 g (0.13 g-at.) of sodium in 500 ml of anhydrous alcohol, heated to 32°, was added in 10 minutes with stirring 320 g (6.05 moles) of acrylonitrile; here the temperature of the reaction mass rose to 45°. The mixture was stirred for 4 hours at 60-62°, maintaining an alkaline reaction medium (to phenolphthalein) by the addition of sodium ethylate solution, then it was neutralized with acetic acid, evaporated, poured into 2.5 liters of 10% NaCl solution, and extracted with ether. The ether solution was washed with 10% Na_2CO_3 solution, then with water, and dried over $CaCl_2$. The yield of the cyanopentanetricarboxylate was 1250 g (80%), b.p. 156-158° (1 mm), n_D^{18} 1.4528.

Found %: C 57.62; H 7.29; N 4.54. $C_{15}H_{23}O_6N$. Calculated %: C 57.46; H 7.40; N 4.47.

3. Preparation of triethyl 1,3,4-pentanetricarboxylate (VIb). A mixture of 219 g (0.70 mole) of the cyano triester (Vb) and 500 ml of concd. HCl was gradually heated for 3 hours up to the boil and then boiled vigorously for 25 hours, periodically disconnecting the reflux condenser to remove the reaction alcohol. The solution was evaporated in vacuo to dryness and the last traces of water were removed by distillation with benzene. The deposit was treated with 200 ml of benzene and a solution of 90 ml of concd. H_2SO_4 in 610 ml of anhydrous alcohol; the mixture was boiled for 24 hours (using a Dean-Stark trap to separate the water formed in the reaction), then vacuum-evaporated, poured into water, and extracted with ether. The mixture of acid esters was separated from the triester, extracting them from the extract with 10% Na_2CO_3 solution, and then they were subjected to further esterification as described above. The total yield of the triester of the pentanetricarboxylic acid was 172 g (85%), b.p. 122-125° (0.5 mm), n_D^{18} 1.4400.

4. Preparation of diethyl 2-methyl-3-cyclopentanone-1,4-dicarboxylate (VIIc). a) Cyclization with sodium ethylate. To a solution of 102 g (4.4 g-at.) of sodium in 1500 ml of anhydrous alcohol was added in a nitrogen atmosphere 1153 g (4.0 moles) of triester (VIb). The mixture was heated on the boiling water bath and with stirring and a slight vacuum the alcohol was completely distilled off in 3-4 hours (toward the end of distillation the reaction mixture foamed strongly and then became thick). The residue was dissolved with heating and stirring in 300 ml of anhydrous toluene, cooled to 0°, diluted with 1 liter of ether, and poured into a stirred mixture of 500 ml of concd. HCl and 1 kg of ice. The ether-toluene solution was washed with 5% $NaHCO_3$, then with 10% NaCl, and dried over $CaCl_2$. The yield of the diester of the methylcyclopentanonedicarboxylic acid was 822 g (85%), b.p. 122-124° (0.6 mm), n_D^{17} 1.4580.

b) Cyclization with sodium. To a stirred suspension of 57 g (2.47 g-at.) of comminuted sodium in 100 ml of anhydrous benzene and 3 ml of anhydrous alcohol at 75° was gradually added 475 g (1.65 moles) of triester (VIb) at such a rate that the mixture boiled moderately. Then the reaction mass was stirred for another 3 hours at 80°, cooled, diluted with 300 ml of ether, and treated as described in Expt. 4a. The yield of the ester of the methylcyclopentanonedicarboxylic acid was 363 g (88%).

5. Preparation of (±)-2-methyl-3-cyclopentanonecarboxylic acid (VIIIb). A mixture of 363 g of the keto diester (VIIc) and 1450 ml of 20% HCl was boiled for 4 hours under reflux, and then for another 4 hours with a descending condenser to remove the alcohol formed in the hydrolysis. The solution was clarified with

charcoal and then vacuum-evaporated to dryness; the residue was recrystallized from ether, using OU-B charcoal. The yield of (±)-2-methyl-3-cyclopentanonecarboxylic acid was 178 g (84%), m.p. 94.2-94.5° (cor.).

Found %: C 59.00; H 6.79. $C_7H_{10}O_3$. Calculated %: C 59.12; H 7.02.

The calcium salt of the acid was obtained as the dihydrate, the same as the calcium salt of dihydrosarkomycin (see Expt. 6b).

Found %: C 46.86; H 6.20; H_2O (of Fischer) 9.88. $C_{14}H_{18}O_6Ca \cdot 2H_2O$. Calculated %: C 46.91; H 6.14; H_2O 10.06.

6. Separation of (±)-2-methyl-3-cyclopentanonecarboxylic acid into its antipodes. a) Preparation of the brucine salts of dihydrosarkomycin and its antipode. A mixture of 42.6 g (0.3 mole) of the racemic acid (VIIIb) and 142 g (0.36 mole) of anhydrous brucine was dissolved with heating in 1700 ml of dry ethyl acetate. A seed crystal of the dihydrosarkomycin brucine salt was added to the hot solution, and then the solution was allowed to cool gradually at room temperature (20-22°), observing the crystallization of the dihydrosarkomycin brucine salt, which deposits as characteristic hexagonal plates. After 3-6 hours with the appearance of the first crystals of the brucine salt of the dihydrosarkomycin antipode, crystallizing as needles, the mother liquor was decanted from the precipitate, and the latter was washed with 50 ml of ethyl acetate. We obtained 30-50 g of the dihydrosarkomycin brucine salt with m.p. 149-151°. The mother liquor and the wash ethyl acetate were combined and heated until the precipitate had dissolved completely, cooled slightly, and seeded with a crystal of the brucine salt of the dihydrosarkomycin antipode, after which the solution was allowed to stand for 4-5 hours.* Then the solution was decanted from the precipitate, which was washed with 50 ml of ethyl acetate. We obtained 25-35 g of the brucine salt of the dihydrosarkomycin antipode with m.p. 130-132°. The ethyl acetate solutions were combined, evaporated to half volume, and the above described process of separating the brucine salts was repeated. The mother liquor was again evaporated, etc. As a total separation result we obtained about 65 g (80%) of the dihydrosarkomycin brucine salt with m.p. 149-151° and about 50 g (60%) of the brucine salt of the dihydrosarkomycin antipode with m.p. 130-132°.

The separation of the brucine salts of dihydrosarkomycin and its antipode can also be accomplished in a thermostat at 35-37°. In 36 hours under these conditions there separates at one time from 60 to 70% of the dihydrosarkomycin brucine salt with m.p. 153-154°.

For further purification the dihydrosarkomycin brucine salt was dissolved in boiling ethyl acetate (1 : 40), the solution treated with charcoal, and a seed crystal introduced. When crystallization was complete the solution was decanted and the precipitate was washed with ethyl acetate. M.p. 154-155°, $[\alpha]_D^{22}$ − 16° (*c* 4 in chloroform).

Found %: C 67.00; H 6.71; N 5.05. $C_{30}H_{36}O_7N_2$. Calculated %: C 67.07; H 6.78; N 5.24.

The brucine salt of the dihydrosarkomycin antipode was purified by recrystallization from moist dichloroethane (1 : 5), and then from ethyl acetate (1 : 8). M.p. 132° $[\alpha]_D^{22}$ − 49° (*c* 3 in chloroform).**

Found %: C 66.78; H 6.74; N 5.28.

b) Preparation of dihydrosarkomycin and its antipode. A mixture of 83 g (0.155 mole) of dihydrosarkomycin brucine salt (m.p. 154-155°) and 412 ml of 5% soda solution (0.250 mole) was boiled for 30 minutes, then cooled to 10°, and the separated brucine removed by filtration. The filtrate was acidified with concd. HCl (to thymol red) and then vacuum-evaporated at 60° to dryness. The dry residue was extracted with hot ether, the ether solution was dried over sodium sulfate, evaporated to incipient crystallization of the acid, and cooled to -15°. The separated dihydrosarkomycin was filtered and washed with cooled ether. Yield 19.7 g (90 %); m.p. 99-100° (from ether), $[\alpha]_D^{21}$ + 69.5° (c 1 in water) see [2]).

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* With longer standing the brucine salt of the racemic acid (needles, m.p. 132°) can begin to crystallize.

** It should be mentioned that for this salt the melting point and the value of the specific rotation cannot serve as reliable criteria of the purity. Consequently, to establish the degree of purity it was necessary to decompose a sample of the salt as described in Expt. 6b, and to determine the constants of the obtained (−)-2-methyl-3-cyclopentanonecarboxylic acid.

Found %: C 59.21; H 6.92. $C_7H_{10}O_3$. Calculated %: C 59.12; H 7.02.

The brucine salt of the dihydrosarkomycin antipode was decomposed in a similar manner. The yield of the (–)-2-methyl-3-cyclopentanonecarboxylic acid was 87%, m.p. 98-99.5° (from ether), $[\alpha]_D^{26}$ – 68.0° (c 1 in water).

Found %: C 59.38; H 6.78.

To obtain the calcium salt 28.4 g (0.2 mole) of dihydrosarkomycin was dissolved in 100 ml of boiling water, 10 g (0.1 mole) of freshly prepared $CaCO_3$ was added, and the still hot solution was filtered. The filtrate was vacuum-evaporated to dryness, the residue was rubbed thoroughly with 45 ml of alcohol, filtered, washed with alcohol, and dried in the air. The yield of calcium dihydrosarkomycin dihydrate was 33.1 g (92%); $[\alpha]_D^{21}$ + 80.2° (based on anhydrous substance, c 1 in water).

Found %: C 46.87; H 6.18; H_2O (of Fischer) 10.30. $C_{14}H_{18}O_6Ca \cdot 2H_2O$. Calculated %: C 46.91; H 6.14; H_2O 10.06.

The dihydrate of the calcium salt of the dihydrosarkomycin antipode was obtained in a similar manner. $[\alpha]_D^{26}$ – 80.0° (based on anhydrous substance, c 1 in water).

Found %: C 46.81; H 6.25; H_2O 10.15.

7. Preparation of tetraethyl 1,3,3,4-pentanetetracarboxylate (VId). A mixture of 945 g (3.0 moles) of the cyano triester (Vb), 750 ml of anhydrous alcohol and 330 ml of concd. H_2SO_4 was boiled for 30 hours, poured into 3 liters of water, and extracted with chloroform. The extract was washed with 5% Na_2CO_3, then with water, and dried over $CaCl_2$. The yield of the tetraethyl ester of the pentanetetracarboxylic acid was 930 g (86%), b.p. 168-170° (3 mm), n_D^{18} 1.4490.

8. Preparation of triethyl 2-methyl-3-cyclopentanone-1,1,4-tricarboxylate (VIIf). a) Cyclization with sodium ethylate. A solution of 102 g (4.4 g-at.) of sodium in 1500 ml of anhydrous alcohol was used to cyclize 1141 g (4.0 moles) of tetraester (VId), the same as described for the preparation of (VIIc) in Expt. 4a. The yield of the ester of the methylcyclopentanonetricarboxylic acid was 1142 g (91%), b.p. 143-146° (0.5 mm), n_D^{17} 1.4600.

b) Cyclization with sodium. A suspension of 34.5 g (1.5 g-at.) of comminuted sodium in 150 ml of benzene and 1.5 ml of anhydrous alcohol was used to cyclize 360 g (1.0 mole of tetraester VId), the same as described for the preparation of (VIIc) in Expt. 4b. The yield of the ester of the methylcyclopentanonetricarboxylic acid was 232 g (74%).

9. Preparation of triethyl 1,1,2-ethanetricarboxylate (IVa). To the sodiomalonic ester, obtained from 480 g (3.0 moles) of malonic ester and 69 g (3.0 g-at.) of sodium in 1200 ml of anhydrous alcohol, with stirring and water-cooling was gradually added 370 g (3.02 moles) of chloroacetic ester and the mixture was heated for 1 hour on the water bath. After the usual treatment we obtained 425 g (58%) of the ester of the ethanetricarboxylic acid, b.p. 134-137° (7 mm), n_D^{20} 1.4305.

10. Preparation of triethyl 4-cyano-1,2,2-butanetricarboxylate (Va). To a solution of 425 g (1.73 moles) of triester (IVa) and 1 g (0.04 g-at.) of sodium in 500 ml of anhydrous alcohol with stirring and water-cooling was added 106 g (2.00 moles) of acrylonitrile at such a rate that the temperature of the reaction mass remained at 27-33°. The solution was stirred for another 2 hours at 35-40°, neutralized with acetic acid, the alcohol vacuum-distilled, the residue poured into water, and then extracted with ether. The yield of the ester of the cyanobutanetricarboxylic acid was 490 g (95%), b.p. 159-160° (1.5 mm).

11. Preparation of triethyl 1,2,4-butanetricarboxylate (VIa). To obtain this ester it is not necessary to isolate the intermediate cyano triester (Va). To the residue obtained in Expt. 10, after distilling off the alcohol,

was added 700 ml of concd. HCl and 300 ml of water; the mixture was heated for 16 hours, then the alcohol formed in the reaction was distilled for 4 hours, and finally the solution was evaporated in vacuo. The residue was esterified by heating with 210 ml of concd. H_2SO_4, 1600 ml of anhydrous alcohol and 200 ml of benzene, the same as described for the preparation of (VIb) in Expt. 3. The yield of the ester of the butanetricarboxylic acid was 425 g (90%), b.p. 116-117° (1 mm), n_D^{18} 1.4395.

12. Preparation of the diethyl esters of 3-cyclopentanone-1,4-dicarboxylic and 3-cyclopentanone-1,2-dicarboxylic acids (VIIa and VIIb). The cyclization of 274 g (1.0 mole) of triester (VIa) with 34.5 g (1.5 g-at.) of comminuted sodium in 700 ml of anhydrous benzene and 2 ml of anhydrous alcohol, and also the separation of the formed isomeric esters, was accomplished by the method of [5]; decomposition of the reaction mass after cyclization was effected by the method of adding 200 ml of concd. HCl, 600 g of ice and 200 ml of ether to the mixture. We obtained 150 g (66%) of the ester of 3-cyclopentanone-1,2-dicarboxylic acid (VIIb), b.p. 110-115° (0.3 mm), n_D^{20} 1.4582, and 27 g (12%) of the ester of 3-cyclopentanone-1,4-dicarboxylic acid (VIIa), b.p. 120-125° (0.7 mm), n_D^{21} 1.4590. Total yield 78%.

13. Preparation of tetraethyl 1,2,2,4-butanetetracarboxylate (VIc). To the residue, obtained in Expt. 10 after distilling off the alcohol, was added a solution of 300 ml of concd. H_2SO_4 in 700 ml of anhydrous alcohol, and the mixture was carefully heated to the boil. On conclusion of exothermic reaction the mixture was heated for another 10 hours, poured into 2 liters of water, and worked up the same as described in Expt. 7. The yield of the ester of the butanetetracarboxylic acid was 490 g (82%), b.p. 165° (2.5 mm).

14. Preparation of the triethyl esters of 3-cyclopentanone-1,1,4-tricarboxylic and 3-cyclopentanone-1,1,2-tricarboxylic acids (VIId and VIIe). 490 g (1.42 moles) of tetraester (VIc) was cyclized with 49 g (2.13 g-at.) of comminuted sodium in 700 ml of anhydrous benzene, the same as described for the preparation of (VIIc) in Expt. 4b. The yield of mixed esters of 3-cyclopentanone-1,1,4-tricarboxylic (VIId) and 3-cyclopentanone-1,1,2-tricarboxylic (VIIe) acids was 290 g (68%), b.p. 135-148° (0.3 mm), n_D^{22} 1.4580.

15. Preparation of 3-cyclopentanonecarboxylic acid (VIIIa). 290 g of mixed keto diesters (VIIa and VIIb) or mixed keto triesters (VIId and VIIe) was hydrolyzed with 1150 ml of 20% HCl, the same as described for the preparation of (VIIIb) in Expt. 5. The yield of 3-cyclopentanonecarboxylic acid was 138 g (85%) in the first case, and 99 g (80%) in the second. M.p. 61.5-62.0° (from ether).

Found %: C 56.02; H 6.31. $C_6H_8O_3$. Calculated %: C 56.24; H 6.29.

SUMMARY

A new path for the synthesis of the racemates of 3-cyclopentanonecarboxylic and 2-methyl-3-cyclopentanonecarboxylic acids was investigated and developed. The latter of these two acids was separated into its antipodes, one of which proved to be identical with dihydrosarkomycin—the reduction product of the antibiotic sarkomycin.

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THE NITRATION OF 1-ETHYLNAPHTHALENE, 4-NITRO- AND 4,5-DINITRO-1-ETHYLNAPHTHALENES

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Levy [1] made a fairly thorough study of the nitration of 1-ethylnaphthalene; he reported the formation of a liquid mixture of nitro compounds that could not be separated into its components by distillation. Nitration was carried out with highly concentrated nitric acid in glacial acetic acid solution. By further transformations Levy established that the main component of the mixture is 4-nitro-1-ethylnaphthalene. Baddar [2] later confirmed Levy's results. In connection with our other researches we decided that it would be of interest to reëxamine the nitration of 1-ethylnaphthaleue. The 1-ethylnaphthalene required in preliminary experiments (G. Ya. Uretskaya) was obtained by reproduction of 1-methylnaphthyl ketone. Results of nitration of 1-ethylnaphthalene and of further transformations of the nitro product agreed with the data of Levy and Baddar, but we modified the procedure for nitration by using nitric acid (d 1.40) without solvent; this facilitated the operation. The main product of nitration was 4-nitro-1-ethylnaphthalene, but the difficulties encountered during distillation of the mixture of nitro compounds and during later transformations clearly indicated that the substances prepared were insufficiently pure.

In later work on nitration (T. S. Safonova) the 1-ethylnaphthalene was prepared by hydrogenation of 1-vinylnaphthalene [3] which excluded the possibility of the presence of β-isomer in the original substance Nitration was carried out under various conditions with nitric acid containing oxides of nitrogen. Chromatographic adsorption was applied to the fractionation of the mixtures of nitro compounds; we had successfully used this method for the fractionation of nitro-1-butylnaphthalenes [4]. The adsorbent was alumina for chromatography (F-2). The mixture of substances obtained by nitration was not distilled before chromatography. Our investigations established: 1) 4-Nitro-1-ethylnaphthalene, 4,5-dinitro-1-ethylnaphthalene and, apparently, 2,4,5-trinitronaphthalene are formed in various ratios depending upon the concentration of nitric acid and the thermal conditions; 2) nitration of 4-nitro-1-ethylnaphthalene gives 4,5-dinitro-1-ethylnaphthalene and 2,4,5-trinitroethylnaphthalene depending upon the reaction conditions; 3) nitration of 4,5-dinitro-1-ethylnaphthalene also gives 2,4,5-trinitro-1-ethylnaphthalene.

The structures of 4-nitro-1-ethylnaphthalene and of 4,5-dinitro-1-ethylnaphthalene were verified by oxidation of these compounds with dilute nitric acid in sealed tubes when 4-nitro-1-naphthoic acid and 4,5-dinitro-1-naphthoic acid were formed respectively.

We inferred the structure of 2,4,5-trinitro-1-ethylnaphthalene via its formation from 4,5-dinitro-1-ethylnaphthalene (which fixes the position of two of the nitro groups) and on the basis of a positive result in the Thompson color reaction* which points to the third nitro group being in the 2 position.

The results of the nitration experiments are represented in the following scheme:

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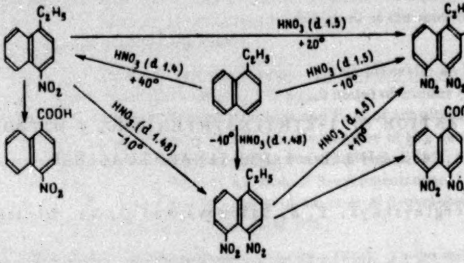
* According to Thompson [5] only those nitro-1-alkylnaphthalenes that contain one of the nitro groups in the 2 position of the naphthalene nucleus give a color reaction with aqueous alcoholic or aqueous acetonic solutions of caustic alkalies.



Although the course of nitration of 1-ethylnaphthalene is generally extremely similar to that of 1-butylnaphthalene [4], a comparison of the corresponding results of nitration performed under identical conditions shows that 1-ethylnaphthalene is nitrated with greater facility.

We reduced 4-nitro-1-ethylnaphthalene to 4-amino-1-ethylnaphthalene and obtained several derivatives of the latter subsituted at the amino group (Safonova and Uretskaya). Reduction was effected catalytically in presence of skeletal nickel catalyst. 4-Amino-1-ethylnaphthalene is a liquid which quickly changes in the air; it must be distilled in a nitrogen atmosphere and in presence of antioxidants.

EXPERIMENTAL

Nitration of 1-ethylnaphthalene

1. Nitration with nitric acid (d 1.40); 4-nitro-1-ethylnaphthalene. a) To 25.5 g 1-ethylnaphthalene (b.p. 133-135° at 17 mm) was added 52 ml nitric acid (d 1.40) at 40° in the course of 45 minutes. The mixture was thereupon stirred for another 30 minutes, poured into 200 ml water and extracted with ether. The ethereal solution was washed with water and dried with calcium chloride. After the ether had been driven off, the residue was distilled in vacuum to give 22.2 g (65%) of substance with b.p. 160-170° at 3 mm. Redistillation gave 13.2 g substance (43%) with b.p. 151-153° at 1.5 mm. The product contains mainly 4-nitro-1-ethylnaphthalene; this method of nitration can also be used for the large-scale production of technical 4-nitro-1-ethylnaphthalene.

b) To 5 ml nitric acid (d 1.40) was added 2.5 g 1-ethylnaphthalene at +40° in the course of 10 minutes, after which the reaction mixture was run into water and the oily substance extracted with ether. The ethereal solution was washed with sodium carbonate solution and water and dried with sodium sulfate. The ether was driven off to leave 3.2 g of brown oil, 3 g of which was chromatogrammed in a column containing 60 g alumina. Elution was effected successively with liqroine, benzene and ethyl alcohol. Elution of the column with ligroine gave 2.4 g (79.8%) oil with b.p. 149-151° at 1 mm; treatment with a mixture of ligroine and benzene gave 0.05 g of intermediate fraction (mixture of oil and crystalline substance); elution of the column with benzene gave 0.24 g crystalline substance with m.p. 169-170° (6.5%); after recrystallization from alcohol the m.p. was 171-172°; the final elution of the column with ethyl alcohol gave 0.3 g resin.

The compound with b.p. 149-151° at 1 mm was distilled in vacuum to give a yellow, viscous oil with b.p. 150-151° at 1 mm, soluble in the common organic solvents, insoluble in water, caustic alkalies and inorganic acids. The elementary analysis corresponds to a mononitro-ethylnaphthalene.

Found %: N 6.80. $C_{12}H_{11}O_2N$. Calculated %: N 6.96.

The substance with m.p. 171-172° forms yellow needles from alcohol, soluble in benzene, carbon tetrachloride, and ethyl acetate, sparingly soluble in ether and gasoline, insoluble in water. The elementary analysis corresponds to a dinitro-ethylnaphthalene.

Found %: N 11.10. $C_{12}H_{10}O_4N_2$. Calculated %: N 11.37.

Oxidation of 4-nitro-1-ethylnaphthalene. A mixture of 2 g 4-nitro-1-ethylnaphthalene (b.p. 150-151° at 1 mm) and 15 ml 11% nitric acid solution was heated in a sealed tube for 8 hours at 165-173°. The product was worked up in the usual manner and gave 0.51 g substance with m.p. 218-219°, rising to 222-223° after 2 recrystallizations from toluene. A mixture with 4-nitro-1-naphthoic acid (m.p. 223-223.5°) melted at 223°.

2. Nitration with nitric acid (d 1.48). To 2 ml nitric acid (d 1.48) was added 0.8 g 4-ethylnaphthalene in the course of 5 minutes with vigorous stirring, the temperature not being allowed to rise above −10°. After 10 minutes stirring the reaction mixture was poured into water. Further treatment was as described in the preceding experiments. Yield 1.2 g dark-brown, oily substance; 1 g of this product was chromatogrammed in a column with 20 g alumina.

Chromatogramming gave 0.1 g (4.6%) 4-nitro-1-ethylnaphthalene (from the fractions obtained by eluting the column with ligroine) and 0.75 g yellow, crystalline substance (benzene eluate) with m.p. 169-170° (71.3%) (after recrystallization from alcohol m.p. 171-172°.). A mixture with 4,5-dinitro-1-ethylnaphthalene (m.p. 171-172°) obtained in the preceding experiment melted at 171°. Subsequent elution of the column with alcohol gave 0.13 g resin.

Oxidation of 4,5-dinitro-1-ethylnaphthalene. A mixture of 0.5 g 4,5-dinitroethylnaphthalene (m.p. 171-172°) and 5 ml 11% nitric acid solution was heated in a sealed tube at 165-170° for 6 hours. The mixture was worked up by the usual method and gave 0.14 g substance with m.p. 258° (rising to 260-261° after recrystallization from aqueous alcohol). A mixture with 4,5-dinitro-1-naphthoic acid melted at 261°.

3. Nitration with nitric acid (d 1.50); 4,5-dinitro-1-ethylnaphthalene and 2,4,5-trinitro-1-ethylnaphthalene. To 2 ml nitric acid (d 1.50) was added 0.8 g 1-ethylnaphthalene at −10° in the course of 10 minutes with good stirring; stirring was continued for another 10 minutes at the same temperature after which the mixture was run into water. Further treatment was as in the previous nitration experiments. Yield 1.4 g viscous oil which crystallized on standing; 1 g of the latter was chromatogrammed in a column of 20 g alumina to give 0.45 g (50%) 4,5-dinitro-1-ethylnaphthalene with m.p. 169-170° (from fractions eluted with benzene), 0.1 g substance with m.p. 125-126° (from fractions removed with a mixture of benzene and carbon tetrachloride) and 0.25 g (23%) of substance with m.p. 198-199° (carbon tetrachloride eluate); the latter had m.p. 199-200° after recrystallization from benzene. Subsequent washing of the column with alcohol gave 0.2 g resins. The substance with m.p. 199-200° formed long, yellow needles (from carbon tetrachloride), soluble in benzene and glacial acetic acid, insoluble in gasoline, ether and water. A mixture of this substance with 4,5-dinitro-1-ethylnaphthalene (m.p. 171-172°) melted at 124-126°. The elementary analysis corresponds to a trinitroethylnaphthalene.

Found %: C 49.62; H 3.15; N 13.88. $C_{12}H_9O_6N_3$. Calculated %: C 49.49; H 3.12; N 14.42.

The substance with m.p. 125-126° is a mixture of dinitroethyl- and trinitroethylnaphthalene. Thompson's color reaction served as guide to the completeness of separation of dinitro from trinitro compound.

Nitration of 4-nitro-1-ethylnaphthalene

1. Nitration with nitric acid (d 1.48); 4,5-dinitro-1-ethylnaphthalene. To 2 ml nitric acid (d 1.48) was added 1 g 4-nitro-1-ethylnaphthalene at −10°, and the reaction mixture was stirred at the same temperature for another 10 minutes before pouring into water. The oily substance was extracted with benzene and worked up as in previous nitrations. Yield 1.2 g oily substance, 1 g of which was chromatogrammed in a column of 20 g alumina. 0.2 g (20%) of the original 4-nitro-1-ethylnaphthalene was obtained (from the combined fractions resulting from elution with ligroine); in addition 0.6 g (60%) of crystalline substance was obtained (from the fractions resulting from elution with carbon tetrachloride); m.p. 171-172° after recrystallization from alcohol; a mixture with the previously prepared 4,5-dinitro-1-ethylnaphthalene (m.p. 171-172°) melted at 171-172°. 0.2 g resins was also obtained (eluted with alcohol).

2. Nitration with nitric acid (d 1.50); 2,4,5-trinitro-1-ethylnaphthalene. To 2 ml nitric acid was added 1 g 4-nitro-1-ethylnaphthalene in 5 minutes at +20°; the mixture was stirred for 10 minutes and poured into water. The oily product was extracted with benzene and worked up as in previous experiments. Yield 1.35 g of substance of which 1 g was chromatogrammed. The fractions collected by elution of the column with benzene gave 0.7 g (65.6%) of substance with m.p. 198-199° (after recrystallization from benzene m.p. 199-200°). Subsequent elution of the column with alcohol gave 0.3 g resins. A mixture of the isolated substance with trinitro-1-ethylnaphthalene (m.p. 199-200°) obtained by nitration of 1-ethylnaphthalene melted at 199°.

Nitration of 4,5-dinitro-1-ethylnaphthalene

To 2 ml nitric acid (d 1.50) was added 1 g 4,5-dinitro-1-ethylnaphthalene at +10°, the mixture was stirred for 10-12 minutes and poured into water. Further working up was as in the preceding experiment. Yield 1.25 g of oily substance of which 1 g was chromatogrammed. In this operation elution of the column with benzene gave 0.55 g of crystalline substance with m.p. 198-199° (after recrystallization from benzene m.p. 199-200°) and 0.4 g resin (alcohol eluate). The crystalline product did not give a depression of melting point with ethyl-trinitronaphthalene obtained from 1-ethylnaphthalene.

4-Amino-1-ethylnaphthalene

To a solution of 5 g 4-nitro-1-ethylnaphthalene in 90 ml ethyl acetate and alcohol (1:1) was added 2 g of skeletal nickel catalyst; the reaction mixture was shaken in a hydrogen atmosphere at normal pressure at 35-40°. The theoretical amount of hydrogen (660 ml) was taken up in 45 minutes. Working up in the usual manner gave 4 g of dark-brown substance which was distilled in vacuum in a nitrogen stream in presence of theethyl ester of 2-mercapto-4-aminobenzoic acid (0.1%). Yield 3.7 g of 4-amino-1-naphthalene (86% of the theoretical): a slightly colored liquid, rapidly darkening in the air; b.p. 130-131° at 0.5 mm; literature data [1-2]: b.p. 162-165° at 7 mm.

4-Acetylamino-1-ethylnaphthalene was prepared by the action of acetic anhydride on 4-amino-1-ethylnaphthalene in benzene solution: colorless crystals with m.p. 149-150°.

4-Benzoylamino-1-ethylnaphthalene. To a solution of 0.5 g 4-amino-1-ethylnaphthalene and 0.45 g dimethylaniline in 8 ml absolute benzene was added a solution of 0.5 g benzoyl chloride in 4 ml absolute benzene; the mixture was heated at 40-45° for 3 hours. The solvent was evaporated off and the white crystals were filtered and washed with a little water and then with ether. Yield 0.66 g of compound with m.p. 196-197° (81% of the theoretical). For analysis the 4-benzoylamino-1-ethylnaphthalene was recrystallized three times from alcohol; plates with m.p. 204-204.5°, soluble in alcohol, benzene and acetone, insoluble in water, caustic alkalies or mineral acids.

Found %: C 82.52; H 6.29; N 5.16. $C_{19}H_{17}ON$. Calculated %: C 82.86; H 6.22; N 5.08.

Ethyl ester of 1,4-ethylnaphthylcarbonic acid. To a solution of 0.5 g 4-amino-1-ethylnaphthalene and 0.45 g dimethylaniline in 8 ml anhydrous benzene was added 0.4 g ethyl chlorocarbonate. The mixture was heated 4 hours at 40-45° and worked up in the usual manner. The solvent was distilled off to leave an oil which partly crystallized on standing. M.p. 84-85° after three recrystallizations from ligroine.

Found %: C 74.32; H 6.97. $C_{15}H_{17}NO_2$. Calculated %: C 74.06; H 7.04.

SUMMARY

1. Nitration of 1-ethylnaphthalene, 4-nitro-1-ethylnaphthalene and 4,5-dinitro-1-ethylnaphthalene was performed under various conditions.

2. Chromatographic adsorption was used for fractionation of the nitro compounds.

3. The structure of 4-nitro-1-ethylnaphthalene, 4,5-dinitro-1-ethylnaphthalene and the position of the two nitro groups in trinitro-1-ethylnaphthalene were confirmed; the probable position of the third nitro group in trinitroethyl-naphthalene was predicted.

4. 4-Amino-1-ethylnaphthalene and some of its derivatives (not described in the literature) were prepared.

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DERIVATIVES OF ALKYLPHOSPHINOUS AND DIALKYLPHOSPHINIC ACIDS

V. ESTERS AND AMIDES OF DIALKYLPHOSPHINIC ACIDS AND THEIR BIOLOGICAL ACTIVITY*

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In the preceding paper [1] we described the preparation of dialkylphosphinic acids by the isomerization method [2]. This method, however, does not permit the preparation of a great variety of esters (especially aromatic), amides and other derivatives of these acids. Our earlier work indicated that the aromatic esters might possess biological activity.

We therefore prepared the acid chlorides of these acids as a preliminary to the preparation of the aromatic esters and other derivatives of dialkylphosphinic acids. These compounds have been studied only to a slight extent [1, 3-5]. Some of the acid chlorides were prepared in yields of up to 85% from esters of dialkylphosphinic acids (synthesized by us previously by the isomerization method [1]) by our method [6] of reaction with phosphorus pentachloride. Some of the acid chlorides were prepared by reacting dialkylphosphinic acids with phosphorus pentachloride [7]. The acid chlorides synthesized are listed in Table 1.

Prep. No.	Formula	Boiling point (pressure in mm in brackets)	d_4^{20}	n_D^{20}	MR_D		Chlorine content (%)		Yield (%)
					found	calc.	found	calc.	
1	$(C_2H_5)_2P(O)Cl$	108—109.5° (16)	1.1394	1.4647	34.07	34.11	25.37, 25.46	25.27	70
2	$(n\text{-}C_3H_7)_2P(O)Cl$	118.5—120 (11)	1.0692	1.4638	43.47	43.25	21.14, 21.17	21.07	80
3	$(iso\text{-}C_3H_7)_2P(O)Cl$	109—110.5 (12)	1.0806	1.4667	43.27	43.25	21.12, 21.08	21.07	65
4	$(n\text{-}C_4H_9)_2P(O)Cl$	142—144 (11)	1.0296	1.4643	52.69	52.48	18.27, 18.31	18.06	87
5	$(iso\text{-}C_4H_9)_2P(O)Cl$	110—110.5 (2)	1.0216	1.4595	52.63	52.48	18.13, 18.09	18.06	85

Some of the acid chlorides (nos. 1,2 and 4, Table 1) are said to have been prepared by Plets [3] and some by Kosolapoff [4, 7]. Comparison of the physical constants and properties of the acid chlorides indicates that Plets probably obtained a mixture of products but not acid chlorides, for the constants of his products were very different from those of our preparations. The substances obtained by Kosolapoff were inadequately characterized.

Aliphatic [8, 9] and aromatic esters were synthesized by alkoxylation with alcohols or reaction with phenols in presence of bases of the prepared acid chlorides. The esters are presented in Table 2.

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* Presented to the All-Union conference on the chemistry and applications of organic compounds of phosphorus in December 1955 at Kazan.

TABLE 2

Preparation number	Formula	Boiling point (mm)	Melting point	d_4^{20}	n_D^{20}	% phosphorus		% nitrogen		Solubility in water ∞	Yield (%)
						found	calculated	found	calculated		
1	$(C_2H_5)_2P(O)OC_6H_5$	132—133° (0.6)		1.0941	1.5164	15.46, 15.51	15.65	—	—	1 : 35	65
2	$(C_2H_5)_2P(O)OC_6H_4CH_3\text{-}o$	138.5—139.5 (0.5)		1.0778	1.5161	14.34, 14.35	14.62	—	—	1 : 80	68
3	$(C_2H_5)_2P(O)OC_6H_4CH_3\text{-}p$	154—155 (0.3)	53.5—54°	—	—	14.37, 14.41	14.62	—	—	1 : 80	72
4	$(C_2H_5)_2P(O)OC_6H_4Cl\text{-}o$	133 (0.25)	—	1.1869	1.5242	13.51, 13.43	13.33	—	—	1 : 300	85
5	$(C_2H_5)_2P(O)OC_6H_4Cl\text{-}p$	134—135 (0.25)	35—38	1.1963	1.5257	13.23, 13.41	13.33	—	—	1 : 250	69
6	$(C_2H_5)_2P(O)OC_6H_4NO_2\text{-}o$	168—170 (0.6)	—	1.2312	1.5324	—	—	5.96, 5.94	5.76	1 : 100	64
7	$(C_2H_5)_2P(O)OC_6H_4NO_2\text{-}m$	171—171.5 (0.3)	—	1.2288	1.5326	—	—	5.72, 5.62	5.76	1 : 150	58
8	$(C_2H_5)_2P(O)OC_6H_4NO_2\text{-}p$	164.5—166 (0.18)	—	1.2356	1.5432	—	—	5.94, 5.95	5.76	1 : 150	66
9	$(n\text{-}C_3H_7)_2P(O)OC_6H_4NO_2\text{-}o$	158.5—160 (0.12)	—	1.1697	1.5224	—	—	5.30, 5.40	5.17	1 : 400	79
10	$(n\text{-}C_3H_7)_2P(O)OC_6H_4NO_2\text{-}m$	174—176 (0.16)	—	1.1710	1.5256	—	—	5.30, 5.24	5.17	1 : 400	70
11	$(n\text{-}C_3H_7)_2P(O)OC_6H_4NO_2\text{-}p$	184—187 (0.28)	—	1.1816	1.5360	—	—	5.27, 5.32	5.17	1 : 450	72
12	$(iso\text{-}C_3H_7)_2P(O)OC_6H_4NO_2\text{-}p$	—	78.5—79.5	—	—	11.51, 11.61	11.43	5.20, 5.27	5.17	1 : 850	80
13	$(n\text{-}C_4H_9)_2P(O)OC_6H_4NO_2\text{-}o$	184—186 (0.35)	—	1.1250	1.5151	—	—	4.75, 4.57	4.68	1 : 2400	72
14	$(n\text{-}C_4H_9)_2P(O)OC_6H_4NO_2\text{-}m$	190—191 (0.2)	—	1.1253	1.5168	—	—	4.82, 4.86	4.68	1 : 2500	70
15	$(n\text{-}C_4H_9)_2P(O)OC_6H_4NO_2\text{-}p$	205—206 (0.28)	—	1.1320	1.5264	—	—	4.81, 4.88	4.68	1 : 2300	60
16	$(iso\text{-}C_4H_9)_2P(O)OC_6H_4NO_2\text{-}p$	176.5—177 (0.15)	41—43	—	—	10.32, 10.19	10.37	4.72, 4.65	4.68	1 : 8000	67

TABLE 3

Preparation number	Formula	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	MR_D		% nitrogen		Yield (%)
					found	calculated	found	calculated	
1	$(C_2H_5)_2P(O)NHC_2H_5$	120.5—122° (0.5)	0.9890	1.4603	41.29	41.43	9.45, 9.51	9.39	50
2	$(C_2H_5)_2P(O)N(C_2H_5)_2$	134—135 (16)	0.9493	1.4564	50.72	50.85	8.02, 8.04	7.90	50
3	$(n\text{-}C_3H_7)_2P(O)N(C_2H_5)_2$	104 (0.22)	0.9278	1.4566	60.08	60.13	6.84, 7.04	6.82	60
4	$(n\text{-}C_4H_9)_2P(O)NHC_2H_5$	157—158 (0.37)	0.9363	1.4598	59.94	59.90	6.59, 6.42	6.82	55
5	$(n\text{-}C_4H_9)_2P(O)N(C_2H_5)_2$	126—127 (0.2)	0.9173	1.4581	69.32	69.32	6.07, 6.16	6.00	70

Treatment with primary or secondary amines gave the corresponding alkylated amides of dialkylphosphinic acids (Table 3).

All the synthesized aromatic esters were found to be biologically active to a greater or lesser extent, and they were much more active than esters of diphenylphosphinic acids [10].

Some of the aromatic esters in question are very strong inhibitors of cholinesterase and have relatively low toxicity. A number of the compounds are capable of causing miosis and of lowering the intraocular pressure.

The relatively good solubility of the esters in water and their stability in aqueous solutions invest them with interest. The amides of dialkylphosphinic acids are not inhibitors of cholinesterase (c.e.) or only mild inhibitors. Some biological characteristics of the individual compounds are given in Table 4.

TABLE 4

Number of substance in Table 2	Toxicity to white mice (mg/kg) LD-50		Miosis in rabbits	Anticholinesterase activity (lowest active concentration)			
				assessed from muscle of frog's abdomen[11]		colorimetric determination by Pravdich-Neminskaya method [12]	
	intravenously	subcutaneously		c.e. of serum	c.e. of rabbit marrow	c.e. of serum	c.e. of rabbit marrow
1	137	Nd*	—	$5 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-3}$
2	75	Nd	—	$5 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-3}$
3	155	Nd	—	$5 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$1 \cdot 10^{-3}$
4	90	Nd	—		$2 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-4}$
5	110	Nd	—	$4 \cdot 10^{-3}$	$4 \cdot 10^{-3}$	$4 \cdot 10^{-3}$	$2 \cdot 10^{-5}$
6	37.5	50	+	$1 \cdot 10^{-3}$	$1 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	$1 \cdot 10^{-6}$
7	19	22.5	+	$2 \cdot 10^{-4}$	$1 \cdot 10^{-5}$	$2 \cdot 10^{-5}$	$2 \cdot 10^{-7}$
8	3.4	4	+	$1 \cdot 10^{-4}$	$2 \cdot 10^{-6}$	$2 \cdot 10^{-6}$	$2 \cdot 10^{-7}$
9	8	17.5	+	$1 \cdot 10^{-5}$	—	$2 \cdot 10^{-6}$	$1 \cdot 10^{-7}$
10	11.2	22.5	+	$5 \cdot 10^{-6}$	—	$1 \cdot 10^{-6}$	$2 \cdot 10^{-8}$
11	6.5	8.7	+	$2 \cdot 10^{-7}$	$2 \cdot 10^{-8}$	$2 \cdot 10^{-8}$	$5 \cdot 10^{-9}$
12	4.2	—	—	$2 \cdot 10^{-5}$	—	$5 \cdot 10^{-6}$	$1 \cdot 10^{-6}$
13	6.6	—	+	$5 \cdot 10^{-6}$	—	$2 \cdot 10^{-6}$	$2 \cdot 10^{-9}$
14	10	—	+	$5 \cdot 10^{-6}$	—	$1 \cdot 10^{-6}$	$2 \cdot 10^{-10}$
15	4.5	7.5	+	$2 \cdot 10^{-6}$	—	$2 \cdot 10^{-7}$	$1 \cdot 10^{-10}$
16	3.7	—	—	$4 \cdot 10^{-5}$	—	$1 \cdot 10^{-5}$	$5 \cdot 10^{-7}$
2 (Table3)	850	1125	—	$1 \cdot 10^{-2}$	—	$2 \cdot 10^{-3}$	$5 \cdot 10^{-4}$

• (Nd) signifies that the toxicity is not determined (subcutaneously) at the solubility characteristic of the given compound.

EXPERIMENTAL

Preparation of dialkylphosphinic acid chlorides. Two methods were used for preparation of the acid chlorides. Our method started from esters of dialkylphosphinic acids which were treated with phosphorus pentachloride in carbon tetrachloride solution, taken in 5-6-fold excess over the ester. At the start the temperature was maintained at 27-30°. After 2/3 of the phosphorus pentachloride had been added, the mixture was heated to 60°, and the remainder was added at this temperature. Heating was continued until the phosphorus pentachloride had disappeared. The solvent and the phosphorus oxychloride formed were driven off in a low vacuum and the residue was distilled in vacuum. Compounds 1, 2 and 4 (Table 1) were so prepared.

In the second method the acids were reacted with phosphorus pentachloride in benzene solution. Compounds 3 and 5 (Table 1) were prepared in this way.

The acid chlorides are colorless liquids with a pungent odor, soluble in ether and other organic solvents. They react violently with water.

Preparation of aromatic esters of dialkylphosphinic acids. All the aromatic esters were prepared from the corresponding acid chlorides by reaction either with phenols in presence of triethylamine or by reaction with the corresponding phenates. By the first method the triethylamine was added to the mixture of phenol and acid chloride in ether solution. By the second method the dry phenate was added to the ether solution of the acid chloride. The reactions were performed in a medium of dry ether at −10°.

The aromatic esters are liquids apart from compounds 3, 5, 12 and 16 (Table 2). The nitrophenol esters are yellow, the others are colorless. Soluble in alcohol, ether and other organic solvents.

Preparation of alkylated amides of dialkylphosphinic acids. The amides were prepared by the reaction of the acid chlorides with amines in the ratio of 1:2 in ether solution at −10°. Colorless, viscous liquids, soluble in water and alcohol. The monoalkylamides are insoluble in ether, differing in this respect from the dialkylamides. The molecular weight of the monoalkylamides corresponds to a dimeric molecule.

SUMMARY

1. A series of previously undescribed acid chlorides, aromatic esters and alkylated amides of diethyl-, dipropyl-, diisopropyl, dibutyl- and diisobutylphosphinic acids were synthesized.

2. A new type of biologically active compound of phosphorus was discovered. It was established that all the aromatic esters of dialkylphosphinic acids synthesized are to various degrees inhibitors of cholinesterase and have a relatively low toxicity. Some of them exercise a miotic action and are stable in aqueous solutions.

3. The nitrophenol esters are more toxic and have a higher anticholinesterase activity.

4. The new alkylated amides of dialkylphosphinic acids are not inhibitors of cholinesterase or are only very weak inhibitors.

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SPATIAL STRUCTURE AND REACTIVITY

VII. THE INTERACTION OF ATOMIC GROUPINGS REMOTE FROM ONE ANOTHER ACCORDING TO THE DATA OF AN INVESTIGATION OF THE KINETICS OF ARYLATION OF 4-AMINODIPHENYL OXIDE AND 4-AMINO-4'-NITRODIPHENYL OXIDE

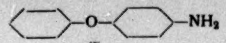
L. M. Litvinenko, R. S. Cheshko and A. D. Gofman

An enormous amount of experimental material has accumulated on the quantitative study by chemical methods of the mutual influence of atoms or atomic groupings in such a simple system as the benzene ring. Only a few disconnected publications have appeared, however, on the study from the same standpoint of more complex aromatic systems containing several benzene rings. In considering such complex systems we must always remember that the character of the interaction of atomic groupings present in different benzene rings is largely governed not only by the well-known capacity of the aromatic system to transmit the electronic influences of the substituents but also frequently by various steric factors associated with the spatial arrangement of the benzene rings from which the compound is built up. For example, on the basis of a study of the kinetics of acylation of a series of amino derivatives of biphenyl we recently showed that the main cause of their unusual reactivity is the occurrence of inhibited internal rotation about the single bond between the benzene rings which determines the geometrical configuration of the molecules of these substances [1-4].

It was of interest to establish whether, and if so for what reason, interaction took place between such markedly different substituents as NO_2 and NH_2 located in opposite rings of compounds differing from the previously studied analogous biphenyl derivatives [1] in that the benzene rings are not directly linked but are separated from one another by a disjunctive bond. We were unable to obtain any guidance in the literature for the solution of such problems from a more or less quantitative standpoint by chemical methods; on the other hand, the optical properties of a series of such systems have been studied.

N. A. Valyashko and V. F. Lavrushin [5, 6] measured the ultraviolet absorption spectra of diphenylmethane and its derivatives and were able to establish that the benzene rings in these compounds interact through the bridge methylene group. A similar conclusion was reached by V. A. Izmailsky and R. S. Tsekhansky [7] in a study of the origin of the color of some derivatives of diphenylmethane and by Jaffe [8] who compared the absorption spectra of a series of compounds of elements of groups V and VI of the periodic system containing phenyl groups. Koch [9] observed that quasi-conjugation takes place in diaryl sulfides between the aromatic rings. Attention was recently drawn to conjugation through NH group [10]. On the other hand, Brode [11] on the basis of the same spectroscopic data arrived at the conclusion that the $-O-$, $-S-$, $-CH_2-$ and $-NH-$ groupings located between unsaturated organic radicals act as isolating groups in the transmission of the electronic interaction of the organic groups. Mangini and Passerini [12] similarly concluded that the sulfur bridge in aromatic sulfides cannot be regarded as a transmitter of conjugation.

The present communication is the first in a series of studies of the above problem with the help of chemical methods. We present here the results of a study of the kinetics of arylation of 4-aminodiphenyl oxide (I) and 4-amino-4'-nitrodiphenyl oxide (II) with p-nitrobenzoyl chloride in benzene solution at 25 and 50°. The data are compared with the results for some previously investigated analogous reactions in the biphenyl series [1].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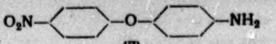
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EXPERIMENTAL

1. Preparation and purification of starting substances. Benzene and p-nitrobenzoyl chloride were purified as described earlier [1]. The amines, after preliminary purification, were repeatedly recrystallized until the melting points were unchanged.

Synthesis of 4-aminodiphenyl oxide. As described in [13], phenol was reacted with p-nitrochlorobenzene in presence of caustic alkali and copper powder. We obtained the best results by using the following modifications of the published method: 1) employment of electrolytic copper powder activated with iodine [14] (see [15]); 2) distillation of the excess p-nitrochlorobenzene with steam prior to distillation of the reaction product in vacuum.

To 10 g 4-nitrodiphenyl oxide dissolved in 100 ml hot methanol was added 7 ml 98% hydrazine hydrate, followed gradually by Raney nickel with maintenance of the conditions previously described in detail [4, 15]. At the end of the reaction (nitrogen no longer evolved) the still-warm solution was filtered and treated with activated charcoal; the 4-aminodiphenyl oxide was then precipitated by addition of 100 ml water. Yield 7.3 g (85%); m.p. 84-85°.

The amine was purified as the hydrochloride by two recrystallizations from hydrochloric acid (1:1). The free amine was regenerated by decomposition of the hydrochloride with hot aqueous ammonia, and was recrystallized from aqueous methanol (1:1) until the m.p. was constant at 85-85.5° (literature [16]: 84°).

Synthesis of 4-amino-4'-nitrodiphenyl oxide. It is reported in the literature [17] that 4,4'-dinitrodiphenyl oxide is readily obtained by heating p-nitrofluorobenzene and potassium p-nitrophenate in presence of copper; under these conditions p-nitrochlorobenzene was found to be entirely unreactive. Our experiments also confirmed this observation but we found that when using activated copper powder (see above) the reaction went with a perfectly satisfactory yield even when using the chloro derivative.

18 g of dry potassium p-nitrophenate* was heated, in a round-bottomed flask of heat-resistant glass fitted with a reflux air condenser, with 90 g p-nitrochlorobenzene in presence of 0.5 g activated copper powder on a paraffin wax bath heated to 245-250°, the mixture being periodically stirred with a copper spatula. A further 3 lots of 0.5 g copper were added at intervals of 5 hours, the total heating period being 20 hours.** The hot melt was then poured into a porcelain dish and pulverized after cooling. The excess p-nitrochlorobenzene was distilled off with steam. The product of reaction was extracted from the residue with several portions of benzene. The extract was treated with activated charcoal and the solvent was evaporated to a small volume; the product was recrystallized once more from benzene. Yield 12 g (45%), m.p. 142-143°, in agreement with the literature [18].

4-Amino-4'-nitrodiphenyl oxide was prepared by adding 80 ml of molar aqueous acetonic solution of sodium disulfide*** portionwise and with shaking in the course of ten minutes to a boiling solution of 10.4 g 4,4'-dinitrodiphenyl after which the mixture was gently boiled for another 15 minutes. It was then made acid to congo with concentrated hydrochloric acid, and the solvent was evaporated nearly to dryness. The amine was extracted with dilute hydrochloric acid (1:1) (several portions of 10 ml each until amine salt x did not crystallize from the last portion. The combined filtrates were treated hot with activated charcoal. The amine hydrochloride that came down on cooling weighed about 2.5 g (24%). The hydrochloride was further purified by two recrystallizations from hydrochloric acid of the same concentration (each time with charcoal).

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* To a hot solution of 50 g p-nitrophenol in 1 liter water was gradually added a 10% KOH solution in 10-15% excess over the equivalent amount, and the liquid was evaporated until a drop placed on a cold glass at once started to crystallize intensively. After cooling, the precipitate was filtered and dried to constant weight at 150°.

** It is not necessary to heat continuously during the whole of the stated period.

*** Prepared by heating 240 g $Na_2S \cdot 9H_2O$ and 32 g sulfur gently with 500 ml water and 250 ml acetone until completely dissolved; the cooled solution was diluted with water to 1 liter.

4-Amino-4'-nitrodiphenyl oxide was separated by decomposition of the hydrochloride with aqueous ammonia and by recrystallization several times from aqueous methanol (2 : 1) until the melting point was constant at 133-134° (the literature reports 130-132° [16] and 134-135° [19]).

II. Procedure for measuring the reaction rate and results obtained. The procedure has been described at length in one of our previous papers [3]; it is based on the interruption of the reaction at a definite instant by addition of a benzene solution of diethylamine, followed by potentiometric titration of unreacted amine with sodium nitrite [20]. The initial concentration of the acid chloride (a), taking into account the equation of the arylation reaction

$$RCOCl + 2ArNH2 \rightarrow RCONHAr + ArNH_2 \cdot HCl,$$

was always equal to one half of the initial concentration of amine (b). The bimolecular velocity constant, the activation energy (E), the exponent of the Arrenhius equation (PZ) and the entropy of activation ($\Delta S^{\#}$) were calculated exactly as described previously [3]. The numerical data for the reaction investigated in the present work are presented in Tables 1 and 2 in which the following symbols are used: t_i are the intervals of time at which the velocity was measured; $\overline{k}_i$ and k are respectively the mean values of the velocity constants 1) for a given t_i and n_i measurements and 2) for all Σn_i measurements. In the second column of these tables are listed the mean yields of the reaction for n_i measurements.

TABLE 1

Kinetics of Arylation of 4-Aminodiphenyl Oxide with p-Nitrobenzoyl Chloride
(a = 0.00125 mol/l; b = 0.0025 mol/l)

25°				50°			
t_i (min.)	Yield (%)	$\overline{k}_i$ (liter/mole · sec)	n_i	t_i (min.)	Yield (%)	$\overline{k}_i$ (liter/mole · sec)	n_i
3	33.2	1.11	2	2	41.0	2.40	4
5	46.6	1.17	5	3	54.3	2.74	3
7	56.6	1.25	5	4	60.1	2.60	3
10	65.6	1.28	5	5	65.1	2.58	4
14	72.3	1.25	6	7	73.7	2.77	3
$k_{25} = 1.23 \pm 0.03$				$k_{50} = 2.60 \pm 0.11$			

$E = 5550$ cal/mole; $PZ = 1.49.10^4$ l/mole · sec.; $\Delta S^{\#} = -41.5$ cal/degree · mole

The data of Table 2 show that the velocity remains substantially unchanged on dilution. The velocity constants obtained at both initial concentrations were a basis for calculation (allowing for the number of individual measurements for each series of experiments) of the mean values, which were then used for calculation of the other kinetic parameters.

Table 3 gives the principal kinetic data for the reactions here investigated, together with some values for our previously studied reactions.

EVALUATION OF RESULTS

Examination of the data of Table 3 indicates that, unlike the phenyl group which has very weak electron-accepting properties [1], the C_6H_5O group has a fairly strong electron-donating action since the velocity constant is more than doubled on passing from aniline to 4-aminodiphenyl oxide. The fact that the rate of arylation of 4-amino-4'-nitrodiphenyl oxide is likewise double the rate for 4-amino-4'-nitrobiphenyl reflects the appreciable drop in electron-repelling ability on passing from the $p-O_2NC_6H_4$ group to the $p-O_2NC_6H_4O$ group.

In comparing the rates of arylation of 4-aminodiphenyl oxide and its 4'-nitro derivative we should have

TABLE 2

Kinetics of Arylation of 4-Amino-4'-nitrodiphenyl Oxide with p-Nitrobenzoyl Chloride

25°				50°			
t_i (min.)	Yield (%)	$\bar{k}_i$ (l/mole·sec)	n_i	t_i (min.)	Yield (%)	$\bar{k}_i$ (l/mole·sec)	n_i
$a = 0.00125$; $b = 0.0025$							
10	14.9	0.117	2	6	19.7	0.282	2
15	19.2	0.106	2	10	28.3	0.272	2
36	35.5	0.103	2	28	51.4	0.261	2
67	49.0	0.0962	2	55	67.2	0.263	2
156	72.3	0.112	2				
$k_{25} = 0.107 \pm 0.005$				$k_{50} = 0.267 \pm 0.010$			
$a = 0.0025$; $b = 0.005$							
4	12.3	0.117	2	4	25.5	0.295	3
8	20.5	0.108	2	5	29.3	0.286	3
15	30.3	0.0972	5	10	44.7	0.279	2
23	38.8	0.0924	3	18	58.2	0.267	3
42	53.9	0.0933	3	28	67.4	0.255	3
80	69.8	0.0967	2				
$k_{25} = 0.0992 \pm 0.0043$				$k_{50} = 0.276 \pm 0.009$			
k_{25} mean $= 0.102 \pm 0.003$; k_{50} mean $= 0.276 \pm 0.009$							

$E = 7500$ cal/mole; $PZ = 3.4 \cdot 10^4$ l/mole·sec; $\Delta S^{\#} = -39.9$ cal/degree·mole

TABLE 3

Kinetic data for Arylation of Amines with p-Nitrobenzoyl Chloride*

Amine	k_{25}	k_{50}	E	$PZ(\cdot 10^{-4})$	$\Delta S^{\#}$
C_6H_5—O—C_6H_4—NH_2-p.	1.23 ± 0.03	2.60 ± 0.11	5550	1.49	—41.5
p-NO_2—C_6H_4—O—C_6H_4—NH_2-p. . . .	0.102 ± 0.003	0.273 ± 0.006	7500	3.4	—39.9
C_6H_5—C_6H_4—NH_2-p[1].	0.533 ± 0.010	1.11 ± 0.02	5600	0.71	—42.8
p-NO_2—C_6H_4—C_6H_4—NH_2-p[1]. . . .	0.0505 ± 0.0011	0.118 ± 0.003	6500	0.29	—44.7
C_6H_5—NH_2[2]	0.580 ± 0.018	—	—	—	—

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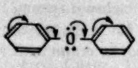
* The dimensions of the parameters are the same as in Tables 1 and 2.

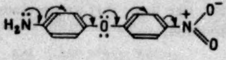
expected that the oxygen atom separating the aromatic rings would lead to considerable weakening of the interaction between the NO_2 and NH_2 groups located at opposite ends of the molecule of diphenyl oxide in comparison with the analogous system of biphenyl. This is by no means the case: the interaction in question is not at all weakened; on the contrary it has even become rather stronger than in the biphenyl system. This is evident from the fact that the ratio of the velocity constants of arylation of 4-aminodiphenyloxide and its

4'-nitro derivative at 25°, in the given case is a measure of the transmission of the interaction of the NO_2 and NH_2 groups through the diphenyl oxide system (factor *f* [4]), is slightly higher (f_{25} = 12.1) than the corresponding ratio for the biphenyl system (f_{25} = 10.6). Consequently the oxygen atom sterically separating the two benzene rings does not in fact function as a barrier between them in the transmission of electronic influences. At the present time it is not easy to account for this observation on the basis of the still scanty experimental material obtained by chemical methods of study. The following considerations, however, are probably relevant.

In diphenyl oxide the distances between the 2,2'- and 6,6'-hydrogen atoms of the different benzene rings is greater than the distances between the corresponding atoms of biphenyl, due to which the spatial interaction of such atoms, which is the cause of the non-coplanar structure of biphenyl [21], should be weakened in diphenyl oxide, for we know that the field effect falls off sharply with the distance [22]. We may therefore suggest that in diphenyl oxide there is less hindrance to the benzene rings taking up the spatial arrangement most favorable to the transmission of interactions between the NO_2 and NH_2 groups than is the x case in the biphenyl system. Interaction between these two substituents leads to the presence at the oxygen of two pairs of p-electrons which participate in the conjugation with the aromatic rings (pπ-conjugation as defined by A. N. Nesmeyanov and M. I. Kabachnik [23]), and this leads to formation of a continuous conjugated system of bonds in the molecule of diphenyl oxide.



In the 4-amino-4'-nitrodiphenyl oxide molecule this conjugation is of course considerably intensified by the presence in its opposed rings of such substituents with a powerful and directionally varied electronic action as the NO_2 and NH_2 groups.



The positive influence of the p-electrons is undoubted in the present case; the only uncertainty is its magnitude. It is not yet clear, however, whether (and to what extent) the transmission of conjugation through the diphenyl oxide system is governed by the angular structure of its molecule [24] and the possibility of alteration of the angle between the C–O–C bonds in such systems under the action of the 4,4'-substituents [25].

It must be left for further work to decide which of the factors discussed above predominates; at present, however, it is indisputable that the effect of the large separation distance between the two substituents in derivatives of diphenyl oxide (relative to the separation distance in analogous derivatives of biphenyl) may be offset or even overshadowed by some new factor capable of promoting the interaction of the NO_2 and NH_2 groups in the system of two benzene rings linked by an oxygen atom.

It should be noted that optical methods of investigation, widely applied to the study of the reciprocal influence of atoms in systems similar to diphenyl oxide do not always give the same insight into the problem of interest to us as the chemical methods. Thus, for example, A. Kh. Khalilov [26] measured the intensity of the lines in the Raman spectra and was able to show that there is considerable interaction between the benzene rings in diphenylmethane and 1,2-diphenylethane across the bridge aliphatic groups, whereas the application of the same method to diphenyl oxide failed to establish whether the benzene rings interact. We can say at once that merely a visual comparison of the intensely orange-red 4-amino-4'-nitrobiphenyl and the light-yellow 4-amino-4'-nitrodiphenyl oxide (4-aminobiphenyl and 4-aminodiphenyl oxide are colorless) readily leads to the conclusion that the interaction between NO_2 and NH_2 groups is very much stronger in the biphenyl derivative. Absorption-spectral measurements do indeed testify to the considerable interaction of these substituents across the biphenyl system [27], whereas according to the spectroscopic data of Szmant and McIntosh [16] the introduction of the 4-amino group into 4'-nitrodiphenyl oxide does not lead to a bathochromic shift in the spectrum of the latter, thereby indicating the absence of a reciprocal effect between the NO_2 and NH_2 groups in the diphenyl oxide system. As already stated, our own data point in exactly the opposite direction, i.e. they indicate that the diphenyl oxide system is a good transmitter of electronic effects. There is no justification for assuming that the conflicting results obtained in the study of the interactions of substituents across the diphenyl system by optical and chemical methods should be attributed to experimental errors in one method or the other. In our opinion the conflicting results are only apparent. The fact is that each method, taken individually, does not enable sufficiently complete characterization of the interaction of substituents in systems of the type here considered. Optical methods primarily afford the possibility of recording the interactions of substituents in systems exhibiting double-bond conjugation (π, π-conjugation [28]), whereas (as evident from our experiments) the chemical methods are also very sensitive in the case of systems with p, π-conjugation. Of interest from this point of view is the paper of V. A. Izmailsky and A. M. Simonov [29] in which the conclusion was reached that the mechanism of transmission of electronic interactions across a conjugated chain changes abruptly when a $-CH{=}CH-$ group in the middle of the chain is replaced by N, O or S atoms. In the opinion of the authors cited, these atoms act as barriers against the effects of conjugation and only transmit inductive effects. We believe that the occurrence of p, π-conjugation can also not altogether be excluded in the present case, for if only inductive effects were developed in the example that we investigated, the introduction of an oxygen atom between the benzene rings should have led to weakening of the interaction of the 4,4'-substituents in the diphenyl oxide system in comparison with the biphenyl system; in this event the inductive effect is markedly quenched with increasing separation distance, but in the present case we did not observe such an effect. It is obvious that more definite conclusions cannot be drawn until a considerable amount of experimental material has been accumulated for these systems by chemical methods.

All that has been said above affords graphic evidence that such an important problem as that of the reciprocal influence of atoms, not directly linked together, in systems of the type of those here considered must be investigated not only by optical methods (and physical methods in general) but also by chemical methods, preference being given to those involving determination of the kinetics and equilibrium of chemical reactions as being the most rigorous and accurate.

Concerning the question of characterization of the reactions here investigated, we limit ourselves for the present to remarking that these reactions, like those that we previously studied [1-4], take place with very low values of energies and entropies of activation.

SUMMARY

1. The kinetics of arylation of 4-aminodiphenyl oxide and 4-amino-4'-nitrodiphenyl oxide were studied.

2. In spite of the fact that an oxygen bridge separates the benzene rings in the diphenyl oxide system, the latter is shown to be as good a transmitter of electronic influences (from one ring to the other) as the biphenyl system in which the benzene rings are directly joined.

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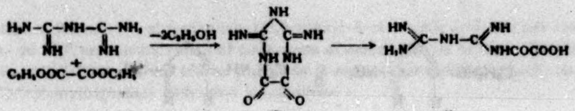
DERIVATIVES OF ω-(2,4-DIAMINO-1,3,5-TRIAZYL-6-)-ALKYLCARBOXYLIC ACIDS

II. INTERACTION OF N'-PHENYLBIGUANIDE WITH OXALIC ESTER

S. V. Sokolovskaya, V. N. Sokolova and O. Yu. Magidson

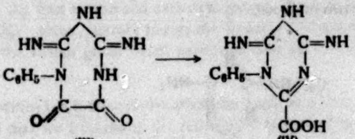
When continuing the investigation [1] of guanamines we recognized the necessity of a systematic study of the ω-(2,4-diamino-1,3,5-triazyl-6-)alkylcarboxylic acid series with gradual increase of the length of the alkyl chain, starting from the simplest guanamine – 2,4-diamino-1,3,5-triazyl-6-carboxylic acid.

In 1910 Rackmann [2] condensed biguanide with diethyl oxalate and believed that a seven-membered ring compound resulted from the reaction; he called the compound "oxalyl biguanide" (I). The latter changed into another substance when treated with caustic alkali or with acid, and Rackmann assigned the structure of biguanide-oxalic acid (II) to the new product.



(I) (II)

Cohn [3] and later Ridi and Checchi [4] likewise assigned a seven-membered ring structure to compounds of the type of (III) obtained by reacting arylbiguanides with diethyl oxalate at the normal temperature. Heating of (III) with water, caustic alkali or acetic acid converts it, according to Ridi [4], into 3-phenyl-4,6-diamino-1,3,5-triazine-2-carboxylic acid (IV).

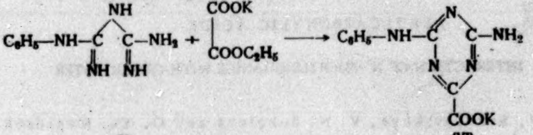


(III) (IV)

Overberger and Shapiro [5] studied the reaction of N'-phenylbiguanide with oxalic ester and isolated a compound of unknown structure which on treatment with caustic alkali changed into 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid, while treatment with alcohols and hydrazine hydrate gave respectively the esters and the hydrazide of the same acid. The authors did not elucidate the structure of the intermediate product which would also have clarified the mechanism of its transformation into 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid.

With the objective of establishing the structure of the intermediate and end products of the reaction of N'-phenylbiguanide (V) with oxalic ester, we studied a number of routes to 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid (VI), prepared its derivatives, effected its decarboxylation and plotted the absorption spectra of these substances.

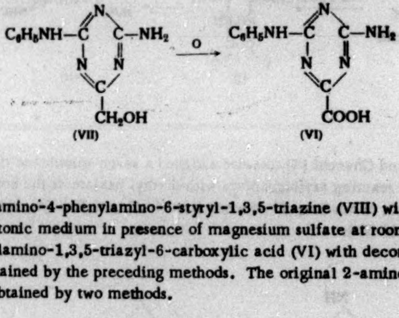
We prepared the potassium salt of the acid by reacting the monopotassium salt of oxalic ester with N'-phenylbiguanide:



(V) (VI)

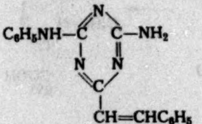
The free acid with decomp. p. 230-231° (subl.) was precipitated from the aqueous solution after acidification with dilute hydrochloric acid (congo test). The isolated acid did not give a depression of melting point when mixed with the acid prepared by reaction of N'-phenylbiguanide with oxalic ester in presence of sodium alkoxide.

Treatment of N'-phenylbiguanide with ethyl glycolate gave 2-amino-4-phenylamino-6-hydroxymethyl-1,3,5-triazine (VII), oxidation of which with potassium permanganate solution in an aqueous acetonic medium at room temperature gave the same acid with decomp. p. 230-231° (subl.).



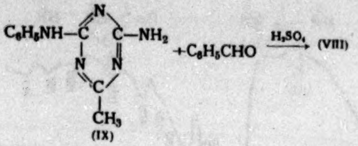
(VII) (VI)

The oxidation of 2-amino-4-phenylamino-6-styryl-1,3,5-triazine (VIII) with potassium permanganate solution in an aqueous acetonic medium in presence of magnesium sulfate at room temperature gave a 40% yield of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid (VI) with decomp. p. 230-231° (subl.), identical with the acid obtained by the preceding methods. The original 2-amino-4-phenylamino-6-styryl-1,3,5-triazine (VIII) was obtained by two methods.



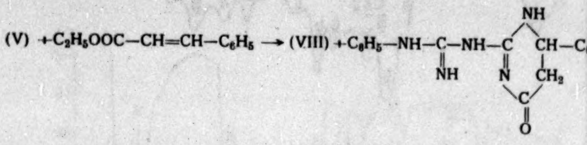
(VIII)

a) By reaction of 2-amino-4-phenylamino-6-methyl-1,3,5-triazine (IX) with benzaldehyde in presence of 3 times the amount of concentrated sulfuric acid.



(IX)

b) In a yield of 15% by condensation of N'-phenylbiguanide with ethyl cinnamate. The main product of the last reaction, judging by the elementary analysis and the infrared absorption spectrum, must be assigned the structure of 2-phenylguanidino-4-phenyl-6-oxo-3,4,5,6-tetrahydropyrimidine (X)



(X)

The structure of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid (VI) was confirmed by its decarboxylation at 250° and measurement of the amount of carbon dioxide evolved. The product of decarboxylation had m.p. 232-233° and was identical with the 2-amino-4-phenylamino-1,3,5-triazine obtained by condensation of N'-phenylbiguanide with ethyl formate [6].

Comparison of the infrared absorption spectra* of acid (VI), its ester and 2-amino-4-phenylamino-6-methyl-1,3,5-triazine (Fig. 1), the presence in them of a strong absorption band in the 1550-1560 cm^{-1} region which is characteristic of the triazine ring [7, 8] confirmed the structure of acid (VI).

A striking feature of the spectrum of the acid (Fig. 1, curve 1) is the absence of the absorption band of the carbonyl group of the carboxyl which is visible in the spectrum of the ester of this acid in the 1725 cm^{-1} region (Fig. 1, curve 2). Also noteworthy is the absence of an absorption band characteristic of the free amino group in the 1656 cm^{-1} region, as is observed in the spectra of the ester of this acid and of 2-amino-4-phenylamino-6-methyl-1,3,5-triazine (Fig. 1, curves 2 and 3). These features can only be accounted for by the existence of the molecule of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid (VI) in the form of an inner salt at the expense of the free amino and carboxyl groups. Such an inner-salt formation, leading to development of the free COO^- anion, sharply lowers the frequency of vibration of the C = O bond to 1380 cm^{-1} [9]; the absorption band of the amino group which participates in the salt formation is shifted into the 1625 cm^{-1} region (Fig. 1, curve 1).

2-Amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid, as prepared by the methods described above, was identical with the acid that we isolated in the reaction of N'-phenylbiguanide with oxalic ester which was carried out under a variety of conditions.

a) Reaction of N'-phenylbiguanide with oxalic ester in a medium of anhydrous alcohol at room temperature resulted after only a few minutes in formation of a yellow precipitate which after purification melted at

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* All the absorption spectra in this paper were plotted in the physico-chemical laboratory of the All-Union Institute of Pharmaceutical Chemical Research under the direction of Yu. N. Sheinker to whom we convey our heartfelt gratitude.

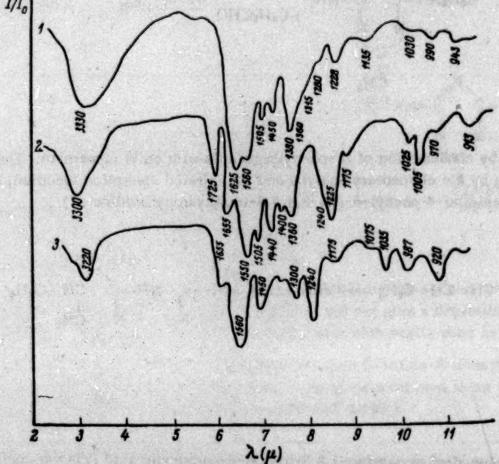


Fig. 1. Infrared absorption spectrum of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid (curve 1), its methyl ester (curve 2) and 2-amino-4-phenylamino-6-methyl-1,3,5-triazine (curve 3). (All in the crystalline state suspended in polyfluorohydrocarbon in vaseline oil).

225-226° (decomp.). The compound dissolved in dilute acids and in sodium hydroxide solutions but was insoluble in solutions of sodium carbonate and bicarbonate. The acid with decomp. p. 229-231° (subl.) was obtained by dissolving the substance in 4% sodium hydroxide solution and acidifying with hydrochloric acid (to congo).

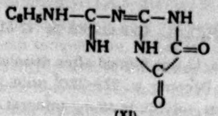
b) Condensation not at room temperature but with boiling for 7 hours led to formation of the ester of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid in 80% yield.

c) Performance of the reaction in presence of sodium alkoxide at once gives 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid without formation of intermediate product.

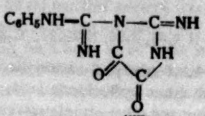
The intermediate product of reaction with m.p. 225-226° (decomp.) has the empirical formula $C_{10}H_9O_2N_5$, i.e. the same as 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid (VI) itself, but its properties are different and it changes into the latter under the action of caustic alkali.

Study of the infrared absorption spectrum of the intermediate substance with decomp. p. 225-226° (Fig. 2) showed that most of the spectrum (the 3300-1300 cm^{-1} and the 1000-600 cm^{-1} regions) was very similar to the spectra of derivatives of parabanic acid and in particular to those of imides of parabanic acid [10]. The absorption band in the 1750-1780 cm^{-1} region is characteristic for the carbonyl group in the 4- and 5-position of the five-membered ring of derivatives of parabanic acid.

The similarity in the infrared spectra and properties of the intermediate compound with m.p. 225-226° and the 2-imide of parabanic acid [11, 12] suggest that the intermediate compound with the empirical formula $C_{10}H_9O_2N_5$ is a derivative of the 2-imide of parabanic acid with the structure of either (XI) of (XII).



(XI)



(XII)

Formation of a compound with a five-membered ring on reaction of N'-phenylbiguanide with oxalic ester is made all the more probable by the fact that one of the products of the analogous reaction of N'-phenylbiguanide with ethyl malonate is 2-phenylguanidino-4,6-dioxopyrimidine, formed as the result of interaction of the ester groups of ethyl malonate with the terminal amino and imino groups of N'-phenylbiguanide which are attached to the same carbon atom.

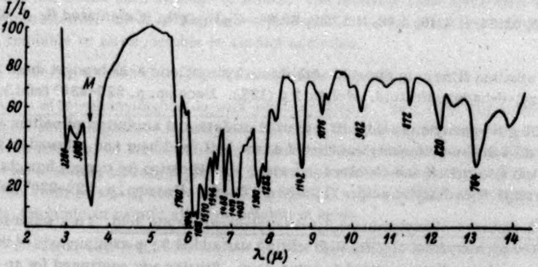
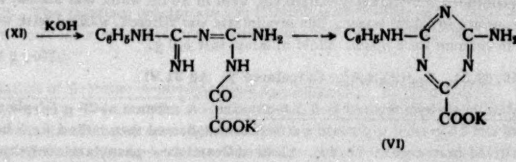


Fig. 2. Infrared spectrum of the compound with decomp. p. 225-226°. (Suspension in vaseline oil.) M - absorption band of vaseline oil.

The following mechanism may be proposed for the transformation of compound (XI) or (XII) into a derivative of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid under the action of caustic alkali solution, hydrazine or alcohols: the CO—NH amido linkage is ruptured (a similar process takes place in the 2-imide of parabanic acid and in parabanic acid itself [13]) with formation of N'-phenyl-N^4-acylbiguanide which then undergoes cyclization to the triazine ring:



(VI)

EXPERIMENTAL

Condensation of N'-phenylbiguanide with dimethyl oxalate. a) To a solution of 3 g N'-phenylbiguanide in 20 ml anhydrous methanol at room temperature was added 4 g dimethyl oxalate. A yellow precipitate was formed in a few minutes, and after 4 hours this was filtered and recrystallized from a large volume of 20%

methyl alcohol. A substance with m.p. 225-226° (decomp.) was obtained. Weight 3.4 g. Light-yellow, fine crystals, insoluble in water and in sodium carbonate or bicarbonate solution, soluble in caustic alkalies and dilute acids.

Found %: C 52.35, 52.33; H 4.09, 3.96; N 29.97. $C_{10}H_9O_2N_5$. Calculated %: C 51.94; H 3.89; N 30.30.

2-Amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid was formed after dissolving the compound in caustic alkali and acidifying with dilute hydrochloric acid. Decomp. p. 229-230° (subl.); a crystalline product poorly soluble in water and alcohol and other organic solvents, soluble in strong mineral acids, caustic alkalies and sodium bicarbonate solution. Contains water of crystallization which is lost on drying in vacuum over phosphorus pentoxide at 100° for 3 ½ days. Relatively easily decarboxylated.

Found %: C 51.51, 51.39; H 4.23, 4.01; N 30.41, 30.34. $C_{10}H_9O_2N_5$. Calculated %: C 51.94; H 3.89; N 30.30.

b) A mixture of 8.5 g N'-phenylbiguanide, 6 g dimethyl oxalate and 20 ml anhydrous methyl alcohol was heated at the boil for 7 hours. The precipitate was filtered and triturated with 4% sodium hydroxide solution; the insoluble material was filtered, washed with water and recrystallized from 75% methyl alcohol. Yield of methyl ester of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid 10 g (80.6%). M.p. 205-206°. Rhombic prisms, soluble in alcohol, sparingly soluble in ether, insoluble in water, soluble in dilute acids.

Found %: C 53.70, 53.64; H 4.49, 4.48; N 28.29, 29.00. $C_{11}H_{11}O_2N_5$. Calculated %: C 53.87; H 4.49; N 28.57.

Treatment of the alkaline filtrate in the cold with dilute hydrochloric acid brought down 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. Weight 1 g (12%). Decomp. p. 229-230° (subl.).

c) A mixture of 35 g N'-phenylbiguanide, 37.5 diethyl oxalate and a solution of sodium alkoxide (5 g metallic sodium in 100 ml anhydrous alcohol) was heated at the boil for 1 hour and allowed to stand for 24 hours. The precipitate was filtered off and dissolved in water. Acidification (to congo) brought down 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. Yield 33 g (72.3%). Decomp. p. 229-230° (subl.).

Potassium salt of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. To a warm solution of 10 g N'-phenylbiguanide in 100 ml anhydrous alcohol with stirring was added 9 g potassium salt of the half ester of oxalic acid. A precipitate immediately started to come down. Stirring was continued for an hour at 50-60°. The following day the precipitate was filtered and washed with anhydrous ethyl alcohol and hot methyl alcohol. Yield of potassium salt of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid 15.2 g (quantitative). Decomp. p. 297-300°. Crystalline substance, readily soluble in water, insoluble in alcohols.

Found %: K 14.71; N 25.75. $C_{10}H_8O_2N_5K$. Calculated %: K 14.52; N 26.02.

Acidification with dilute hydrochloric acid (until acid to congo) gives the free 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid with decomp. p. 229-230° (subl.). A mixture with the acid prepared by the method described above does not show a depression of melting point.

Silver salt of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. To a solution of 5 g potassium salt of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid in 30 ml water was added, with stirring, a solution of 3.2 g silver nitrate in 20 ml water. The precipitate was filtered, washed with water, alcohol and ether, and dried at 100° in vacuum for 3 hours. Yield of silver salt 5.6 g.

Found %: Ag 32.16, 32.31. $C_{10}H_8O_2N_5Ag$. Calculated %: Ag 31.91.

2-Amino-4-phenylamino-6-hydroxymethyl-1,3,5-triazine. A mixture of 20 g N'-phenylbiguanide, 100 ml anhydrous alcohol and 15 g ethyl glycolate was left overnight and then boiled for 3 hours. The precipitate was filtered and recrystallized from alcohol (1:25). Yield of 2-amino-4-phenylamino-6-hydroxymethyl-1,3,5-triazine 13 g (53%). Long, slender plates with m.p. 190-191°, soluble in mineral acids, insoluble in caustic alkalies.

Found %: C 55.39, 55.38; H 4.99, 5.10; N 32.27. $C_{10}H_{11}ON_5$. Calculated %: C 55.30; H 5.07; N 32.25.

Oxidation of 2-amino-4- phenylamino-6-hydroxymethyl-1,3,5-triazine. To a solution of 3 g 2-amino-4-phenylamino-6-hydroxymethyl-1,3,5-triazine in 50 ml purified acetone was added (dropwise with stirring) a solution of potassium permanganate (3 g permanganate in 100 ml water) and 0.5 ml 0.1 N solution of sodium hydroxide at room temperature. After stirring for 2 hours at 20°, the precipitate of manganese dioxide was filtered off and thoroughly washed with weak alkali solution and with water. While cooling, the alkaline filtrate was acidified with hydrochloric acid (1:1) until weakly acid to congo. The precipitate was filtered, washed with water, alcohol and ether and placed in a vacuum-desiccator over phosphorus pentoxide. Yield of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid was 2 g (62.5%). Decomp. p. 229-230° (subl.). A mixture with the acid prepared by condensation of N'-phenylbiguanide with derivatives of oxalic ester did not give a depression of melting point.

2-Amino-4-phenylamino-6-styryl-1,3,5-triazine. 10 g 2-amino-4-phenylamino-6-methyl-1,3,5-triazine [14] was dissolved in 30 g concentrated sulfuric acid; 8 g benzaldehyde was then stirred in and the mixture heated to 90-93° for $1^{1}/_{2}$ hours. The resultant brown, viscous liquid was poured in a thin stream with vigorous stirring into 100 ml cold water. The yellow precipitate was filtered off and washed with water until neutral to litmus, and then with alcohol and ether. It was recrystallized from methanol. This sulfate of 2-amino-4-phenylamino-6-styryl-1,3,5-triazine was dissolved with heating in methyl alcohol and sodium carbonate solution was added until alkaline to litmus. The resultant white precipitate was filtered and recrystallized from methanol. Yield of 2-amino-4-phenylamino-6-styryl-1,3,5-triazine 7 g (49%). M.p. 187-188°. Small needles, insoluble in water, soluble in alcohol and ether.

Found %: N 24.12, 24.01. $C_{17}H_{15}N_5$. Calculated %: N 24.22.

Condensation of N'-phenylbiguanide with ethyl cinnamate. 15 g ethyl cinnamate was added to a warm solution of 12 g N'-phenylbiguanide in anhydrous dioxane, and the mixture was heated on a boiling water bath for 49 hours. After removal of the dioxane the residual oil slowly crystallized. Addition to it of methanol led to separation of snow-white, lustrous crystals of 2-phenylguanidino-4-oxo-6-phenyl-3,4,5,6-tetrahydropyrimidine (weight 5 g) in the form of small, acute-angled rhomboids. M.p. 208-209°. Sparingly soluble in the common organic solvents, insoluble in caustic alkalies, soluble in acids.

Found %: C 66.61, 66.77; H 5.44, 5.65; N 23.11. $C_{17}H_{17}ON_5$. Calculated %: C 66.41; H 5.35; N 22.80.

2-Amino-4-phenylamino-6-styryl-1,3,5-triazine came down from the alcoholic mother liquor after several days. Yield 3 g (15.4%). M.p. 186-187°. A mixture with the styrene derivative obtained from 2-amino-4-phenylamino-6-methyl-1,3,5-triazine did not give a depression of melting point.

Oxidation of 2-amino-4-phenylamino-6-styryl-1,3,5-triazine. 12.5 g of 2-amino-4-phenylamino-6-styryl-1,3,5-triazine was dissolved in 300 ml purified acetone and to the solution was added 13 g of finely pulverized magnesium sulfate hydrate. The mixture was cooled to 15° and dropwise addition was then made, with stirring, of a fine suspension of 18.5 g potassium permanganate in 100 ml water in the course of $1^{1}/_{2}$ hours. Decolorization was instantaneous. Stirring was continued for another 3 hours at 18-20° after the whole of the permanganate had been added. The manganese dioxide was filtered off and washed with water. The acetone was driven off from the filtrate in vacuum; the residual aqueous solution was acidified with hydrochloric acid until acid to congo. The resultant precipitate was filtered, washed with water and with dry acetone and dried in a vacuum-desiccator over phosphorus pentoxide. Yield of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid 4 g (40%).

Decarboxylation of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. 0.4366 g 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid was heated at 250° for 20 minutes. At 230° the compound melted and underwent simultaneous decarboxylation and sublimation. The residue was recrystallized from alcohol. M.p. 232-233°. A mixture with 2-amino-4-phenylamino-1,3,5-triazine [5] did not give a depression of melting point.

Found g: CO_2 0.0747; H_2O 0.0017; residue 0.3602. $C_9H_9N_5$. Calculated g: CO_2 0.0833; 2-amino-4-phenylamino-1,3,5-triazine 0.3534.

Ethyl ester of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. To 2 g of the potassium salt of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid was added 30 ml anhydrous alcohol, and a stream of dry hydrogen chloride was passed through the cooled mixture until the alcohol was completely saturated. The mixture was stood at room temp.. After 3 days, KCl was filtered, alcohol was distilled off in vacuum and the residue (comprising ethyl 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylate and the product of decarboxylation – 2-amino-4-phenylamino-1,3,5-triazine) was fractionated by recrystallization from 75% alcohol. Yield of ethyl 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylate 1 g (53%). Long plates with m.p. 203-204°, soluble in alcohol, insoluble in water and ether.

Found %: C 55.67; H 5.08; N 27.03, 27.03. $C_{12}H_{13}O_2N_5$. Calculated %: C 55.59; H 5.02; N 27.02.

Methyl ester of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. a) Dry hydrogen chloride was passed into a suspension of 2 g 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid in 25 ml methanol with cooling until saturated. The precipitate gradually went into solution. The next day the methanol was driven off in vacuum and the residue was dissolved in water; addition was then made, with cooling, of sodium carbonate solution until alkaline to litmus. The precipitate was filtered off and recrystallized from 85% methyl alcohol. Yield of methyl 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylate 1 g (47.6%). M.p. 205-206°. A mixture with the methyl ester prepared by condensation of N'-phenylbiguanide with oxalic ester did not give a depression of melting point.

b) To a mixture of 2 g of the silver salt of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid and 40 ml anhydrous benzene at 20-22° was added dropwise with stirring, a solution of 0.9 g methyl iodide in 10 ml anhydrous benzene. After the methyl iodide had been added, stirring was continued for another 8 hours. The following day 20 ml methanol was added to the reaction mass which was then heated to the boil and filtered. The alcohol-benzene filtrate was evaporated in vacuum and the residue was recrystallized from 80% methyl alcohol (1 : 40). Yield 0.2 g (14%). M.p. 205-206°.

2-Amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid amide. 0.2 g of methyl 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylate and 10 ml 19% ammonia solution in methyl alcohol were shaken at 30° for 15 minutes until the precipitate had completely dissolved. Within only 5 minutes after the dissolution, a precipitate came down; after 10 hours this was filtered off and recrystallized from methanol. Yield of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid amide 0.18 g (quantitative). M.p. 280-281°. Spindly needles, sparingly soluble in alcohol, insoluble in water and ether.

Found %: C 52.23, 52.41; H 4.67, 4.45; N 36.56, 36.92. $C_{10}H_{10}ON_6$. Calculated %: C 52.17; H 4.38; N 36.50.

Hydrazide of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. 1.3 ml hydrazine hydrate was run into a hot solution of 0.25 g methyl 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylate in 5 ml methanol. The mixture was left to cool at room temperature. After 4 hours the precipitated crystals were filtered, washed with methanol and recrystallized from 50% methyl alcohol. Yield of hydrazide of 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid 0.2 g (80%). M.p. 245-246°. Stout plates, sparingly soluble in alcohol and water, insoluble in ether.

Found %: C 48.45, 48.62; H 4.46, 4.34; N 39.55. $C_{10}H_{11}ON_7$. Calculated %: C 48.97; H 4.52; N 39.98.

SUMMARY

1. The end product of reaction of N'-phenylbiguanide with an oxalic ester is 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid. There is sufficient evidence for concluding that the intermediate product with m.p. 225-226° is a derivative of 2-imidoparabanic acid.

2. The reaction of N'-phenylbiguanide with the monopotassium salt of a half ester of oxalic acid leads to 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid.

3. Oxidation of 2-amino-4-phenylamino-6-hydroxymethyl-1,3,5-triazine and of 2-amino-4-phenylamino-6-styryl-1,3,5-triazine with an aqueous alcoholic solution of potassium permanganate gives 2-amino-4-phenylamino-1,3,5-triazyl-6-carboxylic acid.

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CONDENSATION OF ANILINE, o-TOLUIDINE AND THEIR N-MONOALKYL-SUBSTITUTED DERIVATIVES WITH FORMALDEHYDE IN AN ACID MEDIUM

PREPARATION OF SYMMETRICAL DIAMINODIARYLMETHANES

O. Ya. Fedotova, M. A. Askarov and I.P. Losev

Condensation of aromatic monoamines and their N-monoalkyl-substituted derivatives with formaldehyde has not been studied adequately. The published scientific investigations deal mainly with the study of the composition and properties of resins on their basis. The literature data on methods of synthesis of symmetrical diaminodiarylmethanes in many cases bear an unfinished character and they indicate that the yield of end products (diamines) is relatively low.

We know that the reaction of aromatic monoamines with formaldehyde can go in acid, neutral and alkaline media, the direction depending upon the pH.

The largest number of investigations are concerned with the reaction of aniline with formaldehyde. Thus, experiments carried out in 1894 on the condensation of aniline with formaldehyde in an alkaline medium led to formation of anhydroformaldehyde-aniline with m.p. 139° and methylene-diphenyldiimine with m. p. 64-65° [1]. The authors prepared symmetrical diaminodiarylmethane by heating the products with a large excess of aniline (partly in the form of hydrochloride) in alcoholic solution and obtained a very small amount of 4,4'-diaminodiphenylmethane with a melting point of 85-89°.

N. S. Drozdov [2] established that condensation of aniline with formaldehyde at a pH greater than 7 goes predominantly with formation of methylene-diphenyldiimines which are unstable in media with pH below 7.

With the objective of preparing symmetrical diaminodiarylmethanes, Wagner [3] and later Scanlen [4] performed the condensation of aniline and o-toluidine with formaldehyde in an acid medium. They showed that condensation of 1.1 to 2.5 moles of aromatic amine with 0.5 mole formaldehyde (37% solution) at 50-60° for 12-29 hours gave, apart from resins, a minute amount of symmetrical diaminodiarylmethane.

Braun [5] obtained N, N'-dimethyl-4,4'-diamino-3,3'-dimethyldiphenylmethane in the form of crystals with m.p. 87° by passing HCl through a mixture of 1 mole formaldehyde and 2 moles methyl-o-toluidine.

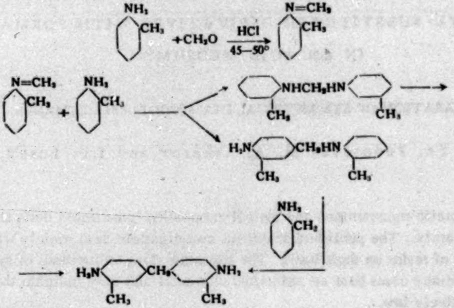
Friedlander [6] prepared N,N'-diethyl-4,4'-diamino-3,3'-dimethyldiphenylmethane with m.p. 93° by heating 30 g ethyl-o-toluidine with 10 ml of 40% formaldehyde solution in an acid medium at 90-110° for 3 hours.

Little study has hitherto been made of the mechanism of condensation of aniline and o-toluidine with formaldehyde with formation of symmetrical diaminodiarylmethanes.

The results of our work on the synthesis of symmetrical diaminodiarylmethanes in 3-3.2 N hydrochloric acid solution at 45-50° agree with those of other workers [2-4] and enable the following reaction scheme to be advanced.

Aniline reacts with facility with formaldehyde, water being split off and methyleneaniline formed. Due to its unsaturated character, the latter quickly polymerizes. At the same time it reacts with aniline with formation of methylenediphenyldiimine and possibly also p-aminobenzylaniline. Under the action of inorganic acids (hydrochloric acid in the present case) methylenediphenyldiimine rearranges to 4,4'-diaminodiphenylmethane. p-Aminobenzylaniline reacts with a molecule of aniline and may also form 4,4'-diaminodiphenylmethane. A large amount of resin is formed at the same time as the diamines.

Condensation of o-toluidine with formaldehyde follows a course similar to that described above and may be represented by the following scheme:



Under our reaction conditions we must assume that of the above-mentioned two directions of reaction, the most probable one is that involving formation of methylenediaryldiimines followed by rearrangement to symmetrical diaminodiarylmethanes.

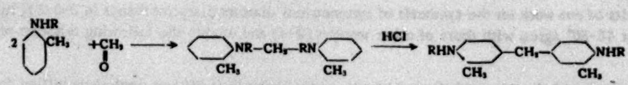
The amino group, being the most active functional group, will react with formaldehyde more rapidly than the hydrogen in the para-position. Formation of the above diamines via p-aminobenzylamines is hardly probable, if only for the reason that this would require a considerable excess of aromatic amine, and this is impossible in our experiments.

Drozdov [2] observed that in the condensation of aniline with formaldehyde the main products are two isomers of diaminodiphenylmethane containing amino groups in the 4,4'- and 4,2'-positions respectively. It would therefore appear that the reaction of aniline with formaldehyde is more complex and that in the first stage, apart from methyleneaniline, methylol derivatives of aniline may be formed which can subsequently yield complex polynuclear products.

It should be pointed out that on passing from aniline to o-toluidine, the condensation results in a yield of diamine 50-85% higher. We know that in the condensation of phenols [6-9] with formaldehyde, two hydrogen atoms in the ortho- and para-positions of the benzene ring participate in the reaction. Aniline is likewise capable of exchanging a ring hydrogen atom, but the replacement of the hydrogen in the ortho-position by a methyl group lowers the number of reactive points and thereby excludes other possible directions of the reaction.

Under the same conditions the condensation of N-monoalkyl-substituted anilines and o-toluidines with formaldehyde takes place with higher yields (96%) than the condensation of aniline and o-toluidine.

The following scheme may be proposed for reactions of N-monoalkyl-substituted o-toluidines with formaldehyde:



In the light of the above considerations the formation of alkyl-substituted aminobenzylamines in the reaction is likewise hardly probable.

Common to both of the above-mentioned schemes is the rearrangement of methylenediaryldiimines under the action of concentrated inorganic acids with formation of symmetrical diaminodiarylmethanes. Confirmation of the proposed schemes and, especially, of the occurrence of rearrangement of diaryldiimines to diaminodiarylmethanes was obtained by experiments on the condensation of p-toluidine with formaldehyde when it was found that 2,2'-diamino-5,5'-dimethyldiphenylmethane was not formed. Other authors also made this observation [10]. The presence of a methyl group in the para-position excludes the possibility of rearrangement of methylene-di-p-tolyldiimine to 2,2'-diamino-5,5'-dimethyldiphenylmethane.

We studied the effect on the yield of symmetrical diaminodiarylmethanes of the concentration of hydrochloric acid, of the temperature and of the duration of reaction.

These experiments showed that the yield of diamine depends on the concentration of HCl, the optimum concentration being 11% (Fig. 1).

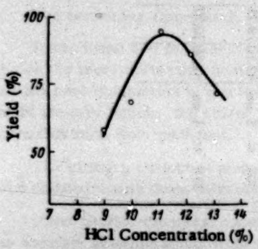


Fig. 1. Influence of HCl concentration on the yield of N,N'-diethyl-4,4'-diamino-3,3'-dimethyldiphenylmethane.

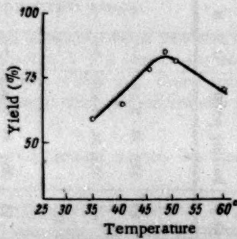


Fig. 2. Effect of reaction temperature on the yield of 4,4'-diamino-3,3'-dimethyldiphenylmethane.

An optimum temperature of 48° was established in the study of the influence of the temperature on the yield of 4,4'-diamino-3,3'-dimethyldiphenylmethane (Fig. 2).

Both lowering and raising of the temperature cause the yield of diamine to drop. The effect of reaction duration on yield of diamine is plotted in Fig. 3 which shows that the reaction is substantially completed in 3-4 hours.

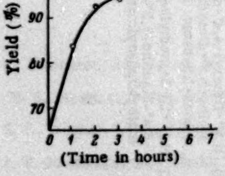


Fig. 3. Influence of duration of reaction on the yield of N,N'-diethyl-4,4'-diamino-3,3'-dimethyldiphenylmethane.

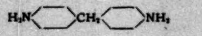
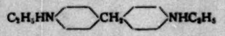
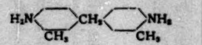
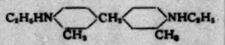
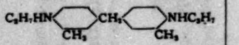
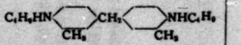
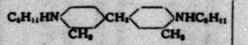
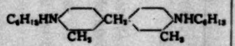
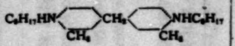
We prepared 9 diamines, four of which (V-IX) are here synthesized and described for the first time. Condensation of the diamines with adipic and sebacic acids gave polyamides ranging from oily products to hard, transparent glasses with m.p. 40-130°, soluble in alcohols, as well as opaque, high-melting polymers with m.p. 300-400°, soluble in phenols.

EXPERIMENTAL

As pointed out above, experiments were run to establish the optimum conditions of formation of symmetrical diaminodiphenylmethanes, a study being made of the effect of concentration of acid, of temperature and of duration of reaction upon the yield of diamines.

On the basis of these experiments a method for

Physico-chemical Constants of Diamines

Preparation number	Name of diamine	Empirical formula from elementary anal.	Structural formula of diamine	Temperature		Found				Calculated				Yield (%)
				m.p.	boiling point	C	H	N	M	C	H	N	M	
(I)	4,4'-Diaminodiphenylmethane.	$C_{13}H_{14}N_2$		89	242 at 2 мм	—	—	14.09	—	—	—	14.13	198.16	59
(II)	N,N'-Diethyl-4,4'-diaminodiphenylmethane	$C_{17}H_{22}N_2$		—	252 at 3 мм	—	—	11.08	—	—	—	11.05	254.37	70
(III)	4,4'-Diamino-3,3'-dimethyldiphenylmethane	$C_{15}H_{18}N_2$		155	—	—	—	12.29	—	—	—	12.37	226.32	85
(IV)	N,N'-Diethyl-4,4'-diamino-3,3'-dimethyldiphenylmethane. . . .	$C_{19}H_{26}N_2$		93	265 at 5 мм	—	—	9.83	—	—	—	9.91	282.40	96
(V)	N,N'-Dipropyl-4,4'-diamino-3,3'-dimethyldiphenylmethane. . . .	$C_{21}H_{30}N_2$		54	276 at 5 мм	81.43	9.76	8.92	311.1	81.24	9.74	9.02	310.44	82
(VI)	N,N'-Dibutyl-4,4'-diamino-3,3'-dimethyldiphenylmethane. . . .	$C_{23}H_{34}N_2$		62	299 at 6 мм	81.76	10.05	8.26	339.5	81.61	10.18	8.27	338.47	83
(VII)	N,N'-Di-2-methylbutyl-4,4'-diamino-3,3'-dimethyldiphenylmethane	$C_{25}H_{38}N_2$		—	298 at 2 мм	81.87	10.34	7.65	363.8	81.91	10.45	7.64	366.57	79
(VIII)	N,N'-Dihexyl-4,4'-diamino-3,3'-dimethyldiphenylmethane. . . .	$C_{27}H_{42}N_2$		—	304 at 5 мм	82.10	10.75	7.12	392.7	82.17	10.72	7.10	394.62	80
(IX)	N,N'-Di-1-methylheptyl-4,4'-diamino-3,3'-dimethyldiphenylmethane	$C_{31}H_{50}N_2$		—	318 at 4 мм	82.50	10.97	6.25	450.0	82.60	11.18	6.22	450.73	81

the preparation of the above-mentioned symmetrical diaminodiarylmethanes was developed. Since they were prepared by an identical procedure, we shall limit ourselves to describing the preparation of (IV) and to mentioning differences in purification and identification tests of the other representatives.

Preparation of N,N'-diethyl-4,4'-diamino-3,3'-dimethyldiphenylmethane

90 ml 36% HCl, 200 ml distilled water and 150 g freshly distilled monoethyl-o-toluidine were charged into a three-necked flask fitted with stirrer, reflux condenser and mercury thermometer.

The solution was cooled to 13-15°, and to the cooled solution with intensive stirring was slowly added 40.5 ml 37% CH_2O solution; during this operation the temperature rose spontaneously to 40° and was held there for 1 hour.

Heating was then continued at 50° on a water bath for 4 hours. The solution was filtered and treated with 10% caustic soda solution until weakly alkaline; white, fairly pure crystals of (IV) came down. They were separated from mother liquor and washed many times with distilled water on a Buchner funnel. Final purification of the diamine effected by two recrystallizations from methanol.

The remaining diamines (I, II, III, V-IX) were prepared in a similar manner.

It was found that diamines (III, IV) could be freed of excess monoamine (after treatment with 10% caustic solution) by recrystallization from methanol. The other diamines (I, II, V-IX), after caustic treatment, were distilled after completion of reaction in vacuum at a residual pressure of 5-10 mm. Compounds II, VII, VIII and IX are oily liquids; the others (I, III-VI) are crystalline substances which are purified with facility by recrystallization from methanol.

The nitrogen content of products (I-IV) was determined by the Kjeldahl method. In all cases the value found coincided with those calculated.

Some physico-chemical constants of aromatic diamines (V-IX) were here determined for the first time; also accurate determinations of the melting points of (I, III, IV) were made; these had not previously been known with certainty (see table). The elementary analysis of (V-IX) and the determination of molecular weight by the cryoscopic method in benzene at K 5.146 likewise confirmed the high degree of purity of the diamines and enabled their empirical formulas to be derived.

SUMMARY

1. Nine representatives of symmetrical diaminodiphenylmethanes were prepared in good yields; five of these (V-IX) are described for the first time.

2. Optimum conditions of condensation were found; the influence of hydrochloric acid concentration, temperature and duration upon the course of the reaction were established in respect of the condensation of aniline, o-toluidine and their monoalkyl-substituted derivatives with formaldehyde.

3. A sharp fall in melting point of the diamines themselves with substitution of one hydrogen atom of an amino group by alkyl radicals of increasing size was established. Alkyl radicals with an odd number of carbon atoms lower the melting point to a greater extent than alkyl groups containing an even number of carbon atoms.

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PREPARATION OF α-CHLOROSULFIDES BY THE DIAZO METHOD

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o-Nitrophenylsulfenechloride is known to react with diazomethane with formation of the corresponding arylchloromethyl sulfide [1]. Attempts to extend this reaction to other aromatic sulfenechlorides, however, were unsuccessful [2]. For example, the reaction of phenylsulfenechloride with diphenyldiazomethane did not lead to the corresponding sulfide [3]. The reaction of aliphatic sulfene chlorides and sulfur halides with diazoalkanes has never before been investigated. However, the similarity of many chemical properties of sulfene halides, which are acid chlorides of sulfenic acids, to those of acid chlorides of carboxylic acids justify the expectation that sulfene chlorides would react with diazoalkanes in accordance with the Arndt-Eistert reaction [4] and would lead in the overwhelming majority of cases to the formation of α-halosulfides. The present work is devoted to this reaction.

The diazo compounds used in this work were diazomethane and diazoethane which were reacted with various sulfene chlorides, namely: ethyl-, β-chlorethyl-, n-propyl-, β-chloro-n-propyl-, benzyl-*, trichloromethyl- and fluorodichloromethylsulfene chlorides. In all cases the corresponding α-chloroalkyl sulfides (Table 1) were obtained.

TABLE 1

Formula	Yield (%)	Boiling point	d_4^{20}	n_D^{20}	Calculated (%)		Found (%)	
					S	Cl	S	Cl
C_2H_5—S—CH_2Cl *	56	50—51° at 16 мм	1.3710	1.5284	—	32.13	—	32.15
C_2H_5—S—$CHClCH_3$ *	68	60 at 15 мм	1.2351	1.5189	—	28.60	—	28.48
$ClCH_2CH_2$—S—CH_2Cl	60.5	79—80 at 15 мм	1.3310	1.5280	22.07	48.97ᵃ	22.27	48.82
$ClCH_2CH_2$—S—$CHClCH_3$ *	55	67 at 9 мм	1.2280	1.5100	20.15	44.59	20.25	44.19
$ClCF_2CF_2$—S—CH_2Cl	55	121—122	1.4351	—	14.75	32.70	15.12	32.48
n-C_3H_7—S—CH_2Cl *	50.8	60—61 at 12 мм	1.0350	1.4801	25.71	28.60	25.44	28.63
n-C_3H_7—S—$CHClCH_3$	65	52—53 at 12 мм	1.0169	1.4712	23.12	25.67	23.44	26.22
$CH_3CHClCH_2$—S—CH_2Cl	59	60—61 at 2 мм	1.2425	1.5230	20.12	44.65	19.49	44.35
$CH_3CHClCH_2$—S—$CHClCH_3$	62	60—61 at 9 мм	1.1591	1.4975	19.07	42.18	19.06	41.60
$C_6H_5CH_2$—S—CH_2Cl *	68.5	108—110 at 8 мм	1.1907	1.5868	18.55	20.58	18.37	20.78
CCl_3—S—CH_2Cl	43	66—67 at 10 мм	1.5911	1.5368	16.00	70.92	15.90	71.00
CCl_3—S—$CHClCH_3$	68.5	36 at 6.5 мм	1.5029	1.5220	14.95	66.30	14.97	66.40
$CFCl_2$—S—CH_2Cl	48.5	58—58.5 at 32 мм	1.5429	1.4890	17.45	58.10	17.64	57.80
$CFCl_2$—S—$CHClCH_3$	58	63—65 at 53 мм	1.4975	1.4760	16.23	53.85	16.13	53.90

Note. Additional analytical data: a) found 25.02% C, 4.63% H; calculated 24.80% C, 4.15% H; b) found 9.86% F; calculated 10.35% F; c) found 10.35% F; calculated 10.62% F. Compounds marked with an asterisk have been described in the literature.

The sulfides are liquids with an unpleasant odor, readily soluble in organic solvents and insoluble in water. They are hydrolyzed by water. Sulfides not containing perhaloalkyl or benzyl radicals react in aqueous alcoholic solution with monochloramine B to form crystalline sulfylimines which melt over a narrow temperature range. Data for the sulfylimines are presented in Table 2. Sulfides containing perhaloalkyl or benzyl radicals do not form sulfylimines.

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* Benzylsulfene chloride has not previously been described. We prepared it by chlorination of benzyl mercaptan or benzyl disulfide.

TABLE 2

Formula	Melting point	Calculated (%)			Found (%)		
		N	S	Cl	N	S	Cl
$C_6H_5SO_2N{=}S(C_2H_5)(CH_2Cl)$	145—146°	5.27	—	—	5.35	—	—
$C_6H_5SO_2N{=}S(C_2H_5)(CHClCH_3)$	150—151	5.01	—	—	5.10	—	—
$C_6H_5SO_2N{=}S(CH_2CH_2Cl)(CH_2Cl)$	124—125	4.67	21.33	23.67[a]	4.76	21.12	23.32
$C_6H_5SO_2N{=}S(CH_2CH_2Cl)(CHClCH_3)$	146—147	4.50	—	—	4.61	—	—
$C_6H_5SO_2N{=}S(C_3H_7\text{-n.})(CH_2Cl)$	143—144	5.01	—	—	5.07	—	—
$C_6H_5SO_2N{=}S(C_3H_7\text{-n.})(CHClCH_3)$	148—149	4.77	—	—	4.81	—	—
$C_6H_5SO_2N{=}S(CH_2CHClCH_3)(CHClCH_3)$	146—147	4.29	19.51	21.65[b]	4.18	19.91	21.50

Note. Additional analyses : a) found 36.18% C, 3.65% H; calculated 36.00% C, 3.67% H; b) found 39.93% C, 4.32% H; calculated 40.24% C, 4.57% H.

Diazomethane reacts with sulfur dichloride and monochloride with the same facility as with sulfene chlorides and forms dichlorodimethyl sulfide and dichlorodimethyl disulfide respectively: $SCl_2 + 2CH_2N_2 \longrightarrow (ClCH_2)_2S + 2N_2$.

The structure of dichlorodimethyl sulfide was confirmed by its chlorination to chloromethylsulfene chloride and by addition of the latter to cyclohexene with formation of chloromethyl-2-chlorocyclohexyl sulfide.

Diazomethane also reacts easily with sulfuryl chloride to form dichlorodimethyl sulfone: $SO_2Cl_2 + 2CH_2N_2 \rightarrow (ClCH_2)_2SO_2 + 2N_2$. This reaction is analogous with the previously described reaction of diazomethane with thionyl chloride which leads to formation of dichlorodimethyl sulfoxide [5].

A study of the reaction of diazoalkanes with fluorides of sulfur acids showed that sulfur difluoride and sulfur monofluoride do not react with dry diazomethane. Failure also attended attempts to react diazomethane with thionyl and sulfuryl fluorides or with methane and chloromethane sulfofluorides. Formation of the corresponding fluoromethyl derivatives was not observed even when using catalysts (copper sulfate).

The diazo method can be extended to anhydrides of sulfur acids. Thus the reaction of diazomethane with moist sulfur dioxide in ethereal solution gives dimethyl sulfite: $SO_2 + H_2O + 2CH_2N_2 \rightarrow (CH_3O)_2SO + 2N_2$.

EXPERIMENTAL

1. Reaction of diazoalkanes with sulfene chlorides. To an ethereal solution of diazoalkane with stirring and cooling to 10° was slowly added an ethereal solution of the equivalent amount of sulfene chloride. The reaction generated heat and led to precipitation of a small amount of substance and to evolution of nitrogen. After completion of the addition the reaction mixture was stood at room temperature for 12 hours. The precipitate was filtered off and the filtrate was evaporated and fractionated in vacuum; the sulfide was isolated from the residue.

A mixture of aqueous solution of monochloramine B and an alcoholic solution of the sulfide was shaken for about half an hour until the oily sulfide had completely disappeared and it was then stood for 24 hours. The precipitated sulfylimine was filtered off and recrystallized from aqueous alcohol.

The reactants were mixed in the reverse order when reacting diazoalkanes with sulfene chlorides containing a trihalomethyl group.

2. Reaction of diazomethane with sulfur dichloride. To a dry ethereal solution of 20.4 g diazomethane was slowly added an ethereal solution of 20 g sulfur dichloride while stirring and cooling to -40°. A violent reaction ensued and a large amount of substance was precipitated while nitrogen was evolved. After the addition

was completed, the mixture was gradually heated to room temperature and allowed to stand for 12 hours. The precipitate was filtered off, the filtrate was evaporated, and the residue was fractionated; two fractionations yielded 8.9 g (36%) dichlorodimethyl sulfide:

B.p. 152-154° at the ordinary pressure, 50-52° at 12 mm; d_4^{20} 1.4058, n_D^{20} 1.5355. Literature data: b. p. 150-155.5° at 760 mm, d_4^{20} 1.4065.

Found %: S 24.30; Cl 54.48. $C_2H_4Cl_2S$. Calculated %: S 24.43; Cl 54.20.

3. Reaction of diazomethane with sulfur monochloride. The experimental conditions were similar to those for the reaction of diazoalkanes with sulfene chlorides. Reaction of 10.7 g diazomethane with 13.4 g sulfur monochloride gave 5.8 g (35.8%) dichlorodimethyl disulfide:

B.p. 107-108° at 18 mm, d_0^{20} 1.4317, n_D^{20} 1.5845.

Found %: S 38.75; Cl 42.91. $C_2H_4Cl_2S_2$. Calculated %: S 39.26; Cl 43.56.

Reaction of 3.3 g dichlorodimethyl disulfide with 1.4 g chlorine in carbon tetrachloride solution at 0° gave 2.4 g (50%) chloromethylsulfene chloride:

B.p. 59-60° at 83 mm, n_D^{20} 1.5490.

Found %: S 27.84; Cl 60.58. CH_2Cl_2S. Calculated %: S 27.35; Cl 60.68.

Reaction of 2.1 g chloromethylsulfene chloride and 1.6 g cyclohexene gave 1.8 g (50.5%) chloromethyl-2-chlorocyclohexyl sulfide (not described in the literature): *

B.p. 121-122° at 6 mm, d_4^{19} 1.2554, n_D^{19} 1.5485.

Found %: S 16.35; Cl 36.08; $C_7H_{12}Cl_2S$. Calculated %: S 16.08; Cl 35.68.

4. Reaction of diazomethane with sulfuryl chloride. An ethereal solution of 15.1 g sulfuryl chloride was slowly added, with stirring and cooling to -40°, to a dry ethereal solution of 9.9 diazomethane. A violent reaction occurred and was accompanied by appearance of a precipitate and evolution of nitrogen. After the addition was complete, the mixture was gradually heated to room temperature and left for 12 hours. The precipitate was filtered off and the filtrate evaporated to a volume of 40-50 ml. The resultant abundant precipitate was filtered off and recrystallized three times from alcohol-ether (1:3). Yield 9.1 g of dichlorodimethyl sulfone, m.p. 69.5-70°.

Found %: S 19.42; Cl 43.37. $C_2H_4O_2Cl_2S$. Calculated %: S 19.63; Cl 43.56.

5. Reaction of diazomethane with sulfur dioxide. 4.4 g sulfur dioxide was passed slowly into an ethereal solution of 5.1 g diazomethane; nitrogen came off and a small precipitate was observed. The reaction mixture was stood for 12 hours. The precipitate was filtered, the filtrate was evaporated and the residue was fractionated. Yield 6.2 g (93%) dimethyl sulfite:

B.p. 125-126°, d_4^{20} 1.2188; n_D^{20} 1.4039. Found %: S 28.70; SO_2 57.80. C_2H_6S. Calculated %: S 29.01; SO_2 58.17.

6. Preparation of benzylsulfene chloride. A reddish brown mixture was formed on passing a gentle stream of chlorine at 0° into 12.4 g benzyl mercaptan until the weight increased by 4.1 g or into a solution of 14.8 g benzyl disulfide into carbon tetrachloride until the weight increase was 4.3 g. After heating for 30-40 minutes and driving off the solvent in vacuum the residue was a red-orange liquid with d_4^{20} 1.136.

Found %: S 20.41; active Cl 21.7 . C_7H_7ClS. Calculated %: S 20.19; active Cl 22.87.

The yields were 16.4 g (93%) and 18.7 g (95%) respectively.

SUMMARY

1. A method for the preparation of α-halosulfides was developed; it involved reaction of aliphatic sulfene chlorides with diazoalkanes.

2. Reactions of diazomethane with sulfur di- and monochlorides, sulfuryl chloride and sulfur dioxide were studied. The respective products were dichlorodimethyl sulfide, dichlorodimethyl disulfide, dichlorodimethyl

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* In literature it is not described.

sulfone and dichlorodimethyl sulfite.

3. Acid fluorides of sulfur acids do not react with diazoalkanes.

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THE SULFONATION REACTION

XLII. PREPARATION AND PROPERTIES OF NAPHTHALENE-1,7-DISULFONIC ACID AND ITS DERIVATIVES

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Naphthalene-1,7-disulfonic acid was first prepared by Armstrong and Wynne in 1890 [1]. It was not until 1934 [2] that it was found in mixtures formed by direct sulfonation of naphthalene, so that the study of its properties had previously been neglected. At the present time it is impossible to overlook the presence of the 1,7-acid in sulfonated mixtures because its amount exceeds 10-15% of the total disulfonic acids [3, 4]. The present work was prompted by the lack of a convenient method of separation of the 1,7-acid from sulfonated mixtures and by the lack of a quantitative method for its determination in the mixtures. We have studied methods of preparation of the 1,7-acid and the properties of some of its derivatives and those of other disulfonic acids of naphthalene which were required for comparison when developing a method of fractionation of the isomers.

Armstrong and Wynne prepared the 1,7-acid from 1-naphthylamine-4,6-disulfonic acid [1] and from 1-naphthylamine-3,5-disulfonic acid [5] by removal of the amino group by the hydrazine method and also by the action of potassium ethyl xanthate on diazotized 2-naphthylamine-8-sulfonic acid followed by saponification and permanganate oxidation [6]. They did not, however, describe the methods. Ufimzew and Kriwoschlukowa [2] found the 1,7-acid in the product of direct sulfonation of naphthalene. Fierz-David and Richter [3] obtained the sodium salt of the 1,7-acid from diazotized 1,7-naphthylamine-sulfonic acid and sulfur dioxide by the Gattermann method, via the sulfinic acid; the yield was about 33%, but they did not characterize the product; the free 1,7-disulfonic acid has not been described.

EXPERIMENTAL

Fractionation of the 1,6-and 1,7-disulfochlorides. The sulfonation of naphthalene-2-sulfonic acid can lead to 20% of 1,7-isomer [2,3,4] and 67% 1,6-isomer [4]. Since the solubility of the dichloride of the 1,7-acid in benzene is 6.9% [2] while that of the 1,6-dichloride is considerably higher, an attempt was made to fractionate them by crystallization from benzene and other solvents.

80 g sodium naphthalene-2-sulfonate was sulfonated in 160 ml chlorosulfonic acid at 60° for 2 hours. The chloride obtained after pouring onto ice had m.p. 90-110° and weighed 80 g (about 70%). It was dissolved in benzene. Addition of a small amount of gasoline led to separation overnight of 29 g of 1,6-dichloride with m.p. 125-127°. Addition of gasoline and cooling led to separation of 31 g of a product with m.p. 90-120° which was dissolved in dichloroethane. About 18 g 1,6-dichloride with m.p. 127° came down after 24 hours. After the solvent had been driven off, the residue of chloro compounds was again dissolved in benzene which then deposited 2.5 g of 1,7-dichloride with m.p. 111-118° after 5 hours, followed by another 2.8 g with m.p. 118-121°; a small amount of 1,6-dichloride later began to separate. In this way about 7% 1,7-dichloride and about 58% 1,6-dichloride were separated from the mixture. The mixture also contains the 2,7-isomer (10-11%) [4], so that the 1,7-dichloride is not smoothly separated, but the 1,6-dichloride is adequately removed. An alternative procedure is to start by separating the 1,6-isomer from dichloroethane and to crystallize the residue for the purpose of isolating the 1,7-isomer from benzene.

The composition of the fractionated components was confirmed by melting point determinations on mixtures with 1,6- and 1,7-dichlorides.

Preparation of 1,7-acid from 1-naphthylamine-7-sulfonic acid. Technical 1-naphthylamine-7-sulfonic acid was dissolved in sodium carbonate and isolated by addition of 6 g sodium chloride per 100 ml solution. 125 g of the salt was diazotized in the usual manner in 1 liter water containing 100 ml conc. sulfuric acid. The diazonium precipitate was filtered and washed and transferred to a solution of disulfide prepared from 130 g crystalline sodium sulfide, 17.5 g sulfur, 150 ml water and 500 g ice. After nitrogen had come off, the reaction mixture was acidified with hydrochloric acid, boiled to drive off hydrogen sulfide and filtered from sulfur; the dinaphthyl-(1)-disulfido-7,7'-disulfonic acid was brought down with a solution of 52 g barium chloride. 85 g of the washed and dried barium disulfido-disulfonate was digested for 4 hours with 20 g sodium carbonate in 1 liter water; after removal of the barium carbonate, the disulfonate was oxidized with a solution of 66 g potassium permanganate for 3 hours. After 2 hours the excess of oxidant was removed with methanol and manganese dioxide was filtered off; the filtrate was acidified with hydrochloric acid, digested with charcoal and evaporated until crystals began to appear. The cooled solution was separated from the crystals (13.5 g) which were a secondary product. Evaporation of the filtrate to dryness gave 59 g sodium salt of naphthalene-1,7 disulfonic acid (dried at 170°). The salt was heated with 175 ml chlorosulfonic acid at 75° for 2 hours to give 32 g dichloride with m.p. 112-115°; after one recrystallization from benzene the product had m.p. 122-122.5°.

The free naphthalene-1,7-disulfonic acid was obtained by saponification of the dichloride in 70% alcohol followed by evaporation. It crystallizes with four molecules of water when kept over solid sodium hydroxide.

Found M 359.8. $C_{10}H_8O_6S_2 \cdot 4H_2O$. Calculated M 360.3.

It retains 2.5 molecules of water when kept over phosphorus pentoxide.

Found M 331.9. $C_{10}H_8O_6S_2 \cdot 2.5H_2O$. Calculated M 333.3.

Solubility of naphthalene disulfochlorides. With the objective of ascertaining which were the best solvents for fractionation of the isomeric disulfochlorides, the solubility of some of them in carbon bisulfide, acetic acid and benzene was determined.

Determinations were carried out in a slightly modified form of the Pavlevsky apparatus [7] with a stirrer and with maintenance in the thermostat at first at 30° for 2-3 hours for saturation of the solution and then at 20 ± 0.1° for 1 to $4\frac{1}{2}$ hours. The amount of dissolved substance was found by weighing the residue after evaporation of the solvent in vacuum.

The results of the determinations (Table 1) show that the 1,6-dichloride is more soluble than the 1,7-isomer in the solvents mentioned, but the difference is too minute to permit successful fractionation.

Salts of naphthalene-1,7-disulfonic acid. Sodium salt. Prepared by neutralization of the free acid with sodium hydroxide. The salt crystallized from the evaporated aqueous solution on addition of alcohol and was dried to constant weight in the air. The air-dry salt contains 4 molecules of water of crystallization which are lost at 100°.

Further heating to 200° of the salt which had been kept at 100° did not result in any further change. The sodium content was determined by calcination in a muffle.

Found %: Na 13.94. $C_{10}H_6O_6S_2Na_2$. Calculated %: Na 13.85.

According to one of the earlier investigations[3] the sodium salt dissolves in water at 17° in the ratio of 1:2.5 and is not salted out from 25% sodium chloride solution. Our determinations showed that 100 g of 24% sodium chloride solution at 20° contains 12.7 g of the sodium sulfonate (average of 12.69 and 12.72). The quantity of dissolved sulfonate was found by determination of sulfur in the residue after evaporation of the solution to dryness.

Magnesium salt. Prepared by neutralizing a solution of the free acid with magnesium carbonate and crystallized from the evaporated solution. The salt was dried in the air and then held at 100, 140 and 200° until constant in weight. The salt dried at 200° contains a $\frac{1}{2}$ molecule of water of crystallization, judging by the magnesia content as determined by calcination.

Found %: Mg 7.62 . $C_{10}H_6O_6S_2Mg \cdot \frac{1}{2}H_2O$. Calculated %: Mg 7.61.

The salt dried at 140° contains 1 molecule of water of crystallization and loses a $\frac{1}{2}$ molecule at 200°.

Found M 329.8. $C_{10}H_6O_6S_2Mg \cdot H_2O$. Calculated M 328.5.

TABLE 1

Solubility (grams per 100 g solutions) of Naphthalene Disulfochlorides at 20 ± 0.1°

Substance	Solvent		
	Carbon bisulfide	Acetic acid 98%	Benzene
1,7-Dichloride	0.67 0.67 0.66	2.37 2.43	6.91 *
1,6-Dichloride	1.55 1.57	4.73 4.77 4.75	
1,5-Dichloride	—	—	5.31 5.35 5.33

*Data of Ufimzew and Kriwoschlukowa.

The salt dried at 100° contains 2 molecules of water; 1 molecule is lost at 140°.

Found M 345.8. $C_{10}H_6O_6S_2Mg \cdot 2H_2O$. Calculated M 346.5.

The air-dry salt contains 8 molecules of water, 6 of which are lost at 100°.

Found M 456.9. $C_{10}H_6O_6S_2Mg \cdot 8H_2O$. Calculated M 454.5.

The magnesium salt is readily soluble in water. Solubility determinations showed that at 20° 100 g solution contains 7.8 g salt (mean of 7.76 and 7.84).

Calcium salt. Likewise prepared by neutralizing a solution of the 1,7-acid with calcium carbonate and crystallized from the evaporating solution. The salt was dried in the air and then held at 100° and 200° until constant in weight. The salt dried at 200° contains 2 molecules of crystal water (on the basis of gravimetric determination of the calcium sulfate).

Found %: Ca 10.93. $C_{10}H_6O_6S_2Ca \cdot 2H_2O$. Calculated %: Ca 11.05.

The salt dried at 100° contains 3 molecules of water; one molecule is lost at 200°.

Found M 383.7. $C_{10}H_6O_6S_2Ca \cdot 3H_2O$. Calculated M 380.2.

The air-dry salt contains 6 molecules of water, 3 of which are lost at 100°.

Found M 433.4. $C_{10}H_6O_6S_2Ca \cdot$ Calculated M 434.2.

The calcium salt readily dissolves in water. At 20°, 100 g of solution contains 21.8 g salt (mean of 21.78 and 21.81).

The amount of salt in the saturated solution was determined by precipitation with ammonium oxalate and by its titration with 0.1 N permanganate solution.

Barium salt. Prepared from 1,7-acid and barium carbonate, and crystallized from the evaporated solution. After drying in the air it was held at 100, 140 and 200° until constant in weight. After holding at 200° the salt contained 1 molecule of water judging by the gravimetric determination of the barium sulfate formed.

Found %: Ba 31.26. $C_{10}H_6O_6S_2Ba \cdot H_2O$. Calculated %: Ba 31.11.

The salt dried at 100° likewise contains one molecule of crystal water since there is no change in weight at 140° and at 200°.

The air-dry salt contains 3 molecules of water, two of which are lost at 100°.

Found M 475.6. $C_{10}H_6O_6S_2Ba \cdot 3H_2O$. Calculated M 477.5.

The barium salt is sparingly soluble in water. Solubility determinations showed that at 20°, 100 g of the solution contains 1.59 g salt (mean of 1.60 and 1.58). The amount of salt in the saturated solution was determined by evaporation of the solvent and calcination of the residue.

The benzidine salt was prepared in crystalline form by adding a heated solution of benzidine hydrochloride to a solution of the free acid. The salt was dried in the air and then held at 100, 140 and 200°. After holding at 200° the salt was anhydrous, as found by titration with 0.1 N alkali in presence of phenolphthalein.

Found M 470.7. $C_{22}H_{20}O_6N_2S_2$. Calculated M 472.2.

The salt dried at 100° contains a $^1/_2$ molecule of water which is lost at 140°.

Found M 485.3. $C_{22}H_{20}O_6N_2S_2 \cdot {}^1/_2 H_2O$. Calculated M 481.2.

The air-dry salt contains 3 molecules of water, $2^1/_2$ of which are lost at 100°.

Found M 528.5. $C_{22}H_{20}O_6N_2S_2 \cdot 3H_2O$. Calculated M 526.2.

The benzidine salt is very poorly soluble in water. The solubility determination showed that at 20°, 100 g of solution contains 0.13 g salt (two determinations).

Data for the salts are summarized in Table 2.

TABLE 2

Salts of Naphthalene-1,7-disulfonic Acids (mean values)

Salts	Number of molecules of water of crystallization temperatures specified				Solubility in water (in g per 100 g solution)
	room	100°	140°	200°	
Sodium	4	0	0	0	12.7 *
Magnesium	8	2	1	0.5	7.8
Calcium.	6	3	—	2	21.8
Barium.	3	1	1	1	1.59
Benzidine	3	0.5	0	0	0.13

SUMMARY

The mixture of naphthalene-1,6- and 1,7-disulfonic acids obtained by sulfonation of sodium naphthalene-2-sulfonate with chlorosulfonic acid was fractionated by crystallization from organic solvents.

A method of preparation of naphthalene-1,7-disulfonic acid is proposed via replacement of the amino group of 1-naphthylamine-7-sulfonic acid by the sulfonic group via dinaphthyl-(1)-disulfido-7,7'-disulfonic acid.

The solubility of naphthalene-1,7-, -1,6- and - 1,5-disulfochlorides in a series of organic solvents was determined.

The sodium, magnesium, calcium, barium and benzidine salts of naphthalene-1,7-disulfonic acid were prepared. Their composition at various temperatures was established and their solubility in water was measured.

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* In 24% sodium chloride solution.

** Original Russian pagination. See C.B. Translation.

THE SYNTHESIS OF 1,2- AND 1,4-BENZENEDISULFONIC ACIDS

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Indirect methods are recommended in the literature for the synthesis of sulfonic acids not formed by direct sulfonation of aromatic compounds. A method widely employed in practice is based on the oxidation of compounds containing sulfur linked to the aromatic nucleus: sulfinic acids, disulfides, thiophenols and esters of xanthic acids which in turn are usually prepared by replacement of the diazo group in the aromatic diazo compounds by the familiar methods of Gattermann [1] and Leuckart [2].

Although the replacement of the diazo group by the sulfinic group by Gattermann's method and its replacement by the ethylxanthic acid residue and other groups by the Leuckart method are feasible in all cases, the yields of polysulfonic acids obtained when applying these reactions rarely exceed 50%. This is due to secondary reactions and to losses suffered when isolating the soluble compounds containing sulfo groups.

Treatment of the diazo compound with sodium disulfide can lead to replacement of the diazo group by the disulfido group. This reaction has been applied to the synthesis of bis-(2-carboxyphenyl)-1)-disulfide from diazotized anthranilic acid [3]. The literature does not record other applications, and it can be regarded as a special reaction. Since bis-(2-carboxy-phenyl-1)-disulfide is obtained in this reaction in nearly quantitative yield and the operations involved in the substitution are simpler than in other methods, we attempted to extend it to other diazo compounds with the objective of using aryl disulfides in the synthesis of polysulfonic acids of the aromatic series, including benzene-1,2- and -1,4-disulfonic acids.

Benzene-1,2-disulfonic acid was first obtained by digesting a solution of 4-bromobenzene-1,2-disulfonic acid with zinc dust in alkali solution[4]. Holleman and Polak [5] later prepared it by potassium permanganate oxidation of a salt of the 2-sulfophenyl ester of ethylxanthic acid, while Drushel and Felty [6] prepared it by oxidation of thiophenol-2-sulfonic acid; the starting substances in the two latter cases were synthesized by the Leuckart method.

Benzene-1,4-disulfonic acid is formed in low yield by direct sulfonation of benzene; the meta-isomer is formed at the same time [7]. Its potassium salt was prepared from diazotized 1-aminobenzene-4-sulfonic acid by the xanthate method described for the 1,2-isomer [6]; Holleman and Polak prepared it via the sulfo-sulfinic acid [5]. A yield of 77% is reported for the barium salt of the 1,2-diacid and one of 55% for the potassium salt of the 1,4-isomer [5], but the purities are not specified.

EXPERIMENTAL

Synthesis of benzene-1,2-disulfonic acid. 17.3 g of 1-aminobenzene-2-sulfonic acid (recrystallized from water and dried) and 5.5 g sodium carbonate were dissolved with heating in 60 ml water. After cooling, the solution was acidified with hydrochloric acid (d 1.18) and diazotized with a solution of 7 g sodium nitrite in 20 ml water at 0-5°. At the same time a solution of sodium disulfide was prepared from 26 g crystalline sodium sulfide in 30 ml water, 3.5 g pulverized sulfur and 20 ml 20% NaOH solution. The diazotized aminosulfonic acid was added in small portions to the alkaline solution of disulfide at 0-5°, care being taken that the medium remained alkaline the whole time and that the temperature did not rise above 20°. The reaction was accompanied by considerable nitrogen evolution and frothing and was completed in 3 hours.

The sodium salt of bis-(2-sulfophenyl)-1)-disulfide, without being separated, was oxidized with saturated potassium permanganate solution at room temperature. The manganese dioxide was filtered off and the filtrate evaporated to dryness on a water bath. The salt of benzene-1,2-disulfonic acid was dried at 130° (without separation of mineral impurities) and converted into the disulfochloride by heating with an equal weight of phosphorus pentachloride at 110 to 170° for 25-30 minutes [8].

Benzene-1,2-disulfochloride was separated from the reaction mass and washed free of acid; it was then light-yellow in color and melted at 132°. Yield 19 g (69.1%); after two crystallizations from benzene it was colorless and had m.p. 142-143° in agreement with the literature [5].

Benzene-1,4-disulfonic acid was prepared from diazotized 1-aminobenzene-4-sulfonic acid (0.1 mole) under similar conditions.

The dry salt of benzene-1,4-disulfonic acid was further purified by conversion to the disulfochloride by heating for 2 hours at 100° with distilled chlorosulfonic acid taken in the proportion of 5 ml per 1 g salt. The reaction mixture was poured onto ice to give 17.6 g (64%) benzene-1,4-disulfochloride with a greyish color and m.p. 128°. After recrystallization from chloroform and then from light gasoline it was colorless and had the literature melting point of 138-139° [5]. When carrying out the syntheses the possibility was verified of isolating the aryl-disulfide from the reaction mass (before oxidation) in the form of the barium salt by salting out with barium chloride. The barium salt of the disulfide was converted to the sodium salt by treatment with sodium carbonate; after removal of the barium carbonate, it was further converted to the disulfochloride as described above. Disulfochlorides prepared by this method had melting points 2-3° higher and the yields ranged from 30 to 40%.

We successfully applied the method of introduction of a sulfo group into an aromatic nucleus via the aryl-disulfide, prepared with the aid of sodium disulfide, to the synthesis of naphthalene-1,8-disulfonic acid [9]. An attempt to effect the replacement of the diazo group by the disulfido group with the help of sodium disulfide in diazotized o-chloroaniline, o-phenetidine and o-toluidine was unsuccessful; mixing of the reactant solutions led to formation of a resinous product which exploded violently on gentle shaking.

Lowering of the temperature to -12° at the instant of reaction and increasing or lowering of the alkalinity of the medium did not eliminate the susceptibility to explosion of the intermediate reaction product.

SUMMARY

Replacement of the diazo group in diazotized 1-aminobenzene-1,2- and 1,4-sulfonic acids by the disulfido group with the help of sodium disulfide was investigated with the objective of introducing the sulfo group into the aromatic nucleus.

Oxidation of the resultant disulfides gave benzene-1,2- and 1,4-disulfonic acids in yields of 69.1 and 64% respectively (as disulfochlorides).

The proposed method of substitution is also applicable to other aminosulfonic acids of the aromatic series.

Reaction of diazo compounds not containing acidic groups with sodium disulfide leads to explosions, and the method of substitution here used is unsuitable for them.

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THE INTERACTION OF HYDRAZINE WITH NITRO COMPOUNDS OF THE ANTHRAQUINONE SERIES

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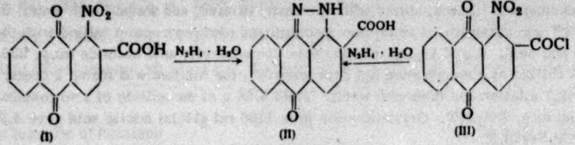
Nucleophilic substitution of a nitro group in the α-position of the anthraquinone molecule is a common method of synthesis of substituted anthraquinones [1]. It is used most frequently for the preparation of amines and alkylamines of the anthraquinone series [2] and in cases when the nitro derivatives are not less accessible than the corresponding halo compounds. Thus, in the industrial synthesis of 1-aminoanthraquinone-2-carboxylic acid and of a series of vat dyes, the substitution of the nitro group by heating with aqueous ammonia is preferred to reduction [3, 4].

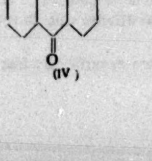
In connection with the possible extension of this synthesis it was of interest to establish whether the nitro group could be substituted with the help of hydrazine since by this means α-haloanthraquinones can be directly converted into pyrazoleanthrone and corresponding derivatives [5-8]. Substitutions of the nitro group by hydrazine mentioned in the literature relate to the preparation of 3-hydrazino-4-nitro-and of 3-hydrazino-4,6-dinitrotoluenes from 3,4-dinitro- and 3,4,6-trinitrotoluenes [9]. The possibility of extending this method to other nitro compounds, utilizing the strong reducing action of hydrazine, is governed by the relative lability of the nitro group and the facility of its reduction which determines the predominant direction of the reaction in dependence on the properties of the nitro compound and the conditions.

Heating of 1-nitro-2-methylanthraquinone with hydrazine hydrate in pyridine gave a mixture of substances, one of which was soluble in aqueous alkali and was identified as 2-methylpyrazoleanthrone, while a second component was 1-amino-2-methylanthraquinone.

Heating of 1-nitroanthraquinone-2-carboxylic acid (I) with hydrazine hydrate in pyridine gave a substance whose elementary composition corresponded to pyrazoleanthrone carboxylic acid (II). The properties of pyrazoleanthrone-2-carboxylic acid obtained by oxidation of 2-methylpyrazoleanthrone [10] and by the action of hydrazine hydrate on 1-chloroanthraquinone-2-carboxylic acid [11] have not been described with sufficient precision for purposes of identification (m.p. above 300°); the preparation of compound (II) from 1-nitroanthraquinone-2-carboxylic acid chloride also indicated another possible structure for compound (IV). For these reasons we considered it was necessary to obtain further confirmation of the structure of (II) by decarboxylation.



(I) (II) (III)



(IV)

Heating of (II) for 25 hours at 180-190° with 20% hydrochloric acid did not cause any change. Sublimation in vacuum likewise did not bring about any change. Decarboxylation with formation of pyrazoleanthrone was effected by sublimation in admixture with copper powder and copper oxide at atmospheric pressure. Treatment of the anilide of 1-nitroanthraquinone-2-carboxylic acid with hydrazine hydrate in pyridine gave the anilide of (II) which on hydrolysis with hydrochloric acid gave (II) and aniline.

Reaction of hydrazine hydrate in pyridine with 1-amino-4-nitroanthraquinone-2-carboxylic acid yielded 1,4-diaminoanthraquinone-2-carboxylic acid together with the product of its decarboxylation – 1,4-diaminoanthraquinone; this reaction is evidently associated with the lower mobility of the nitro group which depends on the decrease in the positive charge of the carbon linked to it under the influence of the amino group in the para-position.

EXPERIMENTAL

4.1 g hydrazine hydrate was added to 8 g 1-nitro-2-methylanthraquinone (m.p. 268-270°) in 100 ml pyridine; the mixture was stirred for 3 hours at 115°, cooled, diluted with 500 ml water and filtered, and the precipitate was washed with water. Yield 5.88 g substance which was boiled with 8.5 liters of 2% NaOH solution and filtered hot. Treatment of the filtrate with hydrochloric acid gave 3.42 g of substance with m.p. 304-307° (the literature reports 298-300° [7]). Three crystallizations from glacial acetic acid gave rhombic, yellow-orange crystals of 2-methylpyrazoleanthrone with m.p. 318.6-319.2°.

λ_{max} 400 mμ; $\epsilon \cdot 10^{-4}$ 2.72 (in ethanol).

Found %: C 76.57, 76.66; H 4.43, 4.33; N 11.86, 11.79. $C_{15}H_{10}ON_2$. Calculated %: C 76.90; H 4.91; N 11.96.

2.3 g of precipitate insoluble in hot NaOH solution has m.p. 205-206°. A mixture with 1-amino-2-methylanthraquinone (m.p. 202-203°) melts at 203-204.5°.

12 g of 1-nitroanthraquinone-2-carboxylic acid with m.p. 285-286° and 6.2 g hydrazine hydrate in 120 ml pyridine were stirred 3 hours at 115°. After cooling and filtering, the product was washed with 20 ml pyridine and then with water. 3.93 g of orange substance was obtained; insoluble in dilute acids, soluble in aqueous bicarbonate, soda, caustic alkali and concentrated sulfuric acid. The melting point is above 340°. The compound was dissolved in 56 ml H_2SO_4 (chem. pure) and 15 ml water was added; the precipitate was filtered off, stirred with hot water, filtered, and washed with acid. Yield 2.76 g of pyrazoleanthrone-2-carboxylic acid.

λ_{max} 420 mμ; $\epsilon \cdot 10^{-4}$ 2.09 (in ethanol).

Found %: C 68.05; H 2.95; N 10.54, 10.57. $C_{15}H_8O_3N_2$. Calculated %: C 68.15; H 3.05; N 10.58.

Heating of the substance with copper powder and copper oxide gave a compound insoluble in aqueous $NaHCO_3$ solution with m.p. 279-281°. A mixture with pyrazoleanthrone* with m.p. 286-287.5° (the literature reports 277-278° [5] and 288-289° [12]) melts at 284-286.5°. 7.02 g 1-nitroanthraquinone-2-carboxylic acid chloride (m.p. 236.5-237.5°) and 4.12 g hydrazine hydrate were boiled for 3 hours in 120 ml pyridine; the mixture was cooled and filtered, and the precipitate washed with 25 ml pyridine and then with water. Yield 4.14 g product; this was dissolved in 6.3 ml sulfuric acid (chem.pure) and 2.5 ml water was added. The precipitate (yellow needles) was filtered, stirred with hot water, filtered, and washed with water. 3.42 g of substance with m.p. above 340° was obtained; its absorption spectrum and nitrogen content tallied with those of pyrazoleanthrone-2-carboxylic acid. 7 g of 1-nitroanthraquinone-2-carboxylic acid chloride (m.p. 236.5-237.5°) was brought into 40 ml aniline at a temperature not exceeding 30°; the mixture was stirred 2 hours, filtered, washed with 20 % HCl solution and then with water. Yield 6.56 g of the anilide of 1-nitroanthraquinone-2-carboxylic acid with m.p. 268-270°. Crystallization from 1100 ml glacial acetic acid gave 4.97 g of yellow prisms with m.p. 278.5-279.5°.

Found %: N 7.54, 7.58. $C_{21}H_{12}O_5N_2$. Calculated %: N 7.52.

1.3 g of the anilide of 1-nitroanthraquinone-2-carboxylic acid was boiled with 4.12 g hydrazine hydrate in 15 ml pyridine for 2 hours. The solution was diluted with 60 ml water and filtered; the precipitate was washed with water. Yield of anilide of pyrazoleanthrone-2-carboxylic acid 0.9 g. Yellow powder, m.p. 310-312° (decomp.), insoluble in aqueous bicarbonate and soda; soluble in dilute NaOH solution with a red coloration and in conc. sulfuric acid.

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* Pyrazoleanthrone was purified by precipitation as sulfate by fractional dilution of the solution in concentrated sulfuric acid.

Found %: C 74.07, 73.82; H 3.71, 3.44; N 12.54, 12.58. $C_{21}H_{13}O_2N_3$. Calculated %: C 74.33; H 3.86; N 12.48.

Hydrolysis by heating with 20% hydrochloric acid for 12 hours at 180-190° gave pyrazoleanthrone-2-carboxylic acid and aniline.

2 g of 1-amino-4-nitroanthraquinone-2-carboxylic acid and 2 g hydrazine hydrate were heated at the boil in 20 ml pyridine. The solution became deep blue. To the cooled solution was added 30 ml hydrochloric acid (d 1.14). A precipitate (1.71 g) was obtained which was soluble in aqueous bicarbonate, soda and caustic alkali. It dyes wool from an acid bath. Chromatography of the alcoholic solution (0.4 g) on alumina gave 0.1 g substance whose melting point did not show a depression in a mixed test with 1,4-diaminoanthraquinone, and 0.27 g of 1,4-diaminoanthraquinone-2-carboxylic acid.

Found %: N 10.09. 10.29. $C_{15}H_{10}O_4N_2$. Calculated %: N 9.93.

SUMMARY

The action of hydrazine on α-nitro compounds of the anthraquinone series (1-nitromethylanthraquinone, 1-nitroanthraquinone-2-carboxylic acid and its acid chloride and anilide) results in substitution of the nitro group and simultaneous closure of the pyrazole ring with formation of substitute pyrazoleanthrone. In the case of presence in the anthraquinone nucleus of substituents that lower the mobility of the nitro group, the main direction of the reaction is reduction of the nitro group. Reaction of hydrazine with 1-amino-4-nitroanthraquinone-2-carboxylic acid gave 1,4-diaminoanthraquinone-2-carboxylic acid.

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[illegible]

Found %: C 74.57, 75.88; H 5.71, 5.90; [illegible]. Calculated %: [illegible]

Hydrolysis by heating with 80% sulfuric acid for 20 hours at 180° gave [illegible] phthalic acid and [illegible].

7 g of 1-amino-4-nitro[illegible] and 1 g [illegible] in 30 ml pyridine. [illegible]

Found %: [illegible]. Calculated %: [illegible].

SUMMARY

[illegible]

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[12] [illegible]

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A NEW TYPE OF TRANSFORMATION OF TERPENES

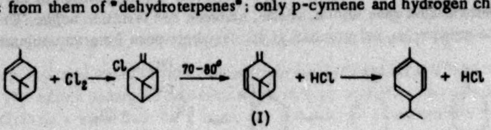
XVIII. DEHYDROTERPENES

D. Tishchenko and T. Danilova

The following results were obtained in our earlier studies: the chlorination of α-pinene and fractionation of the reaction products at 10-20 mm gives a fairly large amount of p-cymene due to partial breakdown of the monochloroterpene [1]; the chlorination of α-terpinene gives, apart from 1,4-dichloro-p-menthadiene-2, p-cymene [2]; the reaction of 2-chlorosabinene with potassium acetate leads to formation of the ester of sabinelol as well as an orange "dehydroterpene" $C_{10}H_{14}$, which is apparently thujadiene-1,(7), 2 [3]; under the same conditions 4-chloro-p-menthadiene-1,8 (9) gives mainly the "dehydroterpene" $C_{10}H_{14}$ and its polymer and a small quantity of ester, while 3-chloro- Δ^4-carene gives $C_{10}H_{14}$ and an ester [4]; finally the chlorination of β-pyronene gives a mixture of "dehydroterpene" and a terpene monochloride [5]. It was also observed that during distillation of the product of chlorination of Δ^3-carene the decomposition of the chloride increases with the residual pressure, although the products of decomposition were not identified [6]. The "dehydroterpenes" mentioned above are very unusual hydrocarbons: they boil 15-20° higher than the original terpenes; their specific gravity is higher than that of the terpenes by 0.026-0.027, and the refractive index is 0.034-0.038 higher. These constants are higher than those of p-cymene which is one of the "dehydroterpenes" but belongs to the aromatic series. The method of preparation of all the "dehydroterpenes" that we obtained makes it inevitable that they should contain a system of two or three conjugated double bonds. A.A. Petrov later prepared a series of hydrocarbons isomeric with benzene hydrocarbons, but some of them had isolated double bonds and their physical constants were therefore lower [7]. Finally in 1955 Bailey et al. obtained excellent yields of 1,2-dimethylene-5-methyl-cyclohexene-4- and 1,2-dimethylene-4,5-dimethylcyclohexene-4 by pyrolysis at 500° of the acetic esters of substituted dimethyloltetrahydrobenzenes [8]. The latter authors point out that these compounds are only isomerized after heating for a sufficiently long period in an organic solvent in presence of small amounts of inorganic acids. Their formation by pyrolysis at 500° points to their high thermal stability. This fact merits attention as indicating that the valence electrons of "dehydroterpenes" and their homologs have a very low mobility; in the absence of inorganic acids the isomerization to benzene hydrocarbons does not take place in spite of the high thermodynamic probability of this transformation.

A.A. Petrov assigned particular structures to the hydrocarbons that he prepared on the basis of the method of preparation. Bailey confirmed the structure for his two hydrocarbons. The relative ease of isomerization of "dehydroterpenes" and their homologs into benzene hydrocarbons is undoubtedly bound up in some way with their structure. The importance of confirming the structure in each individual case is therefore obvious.

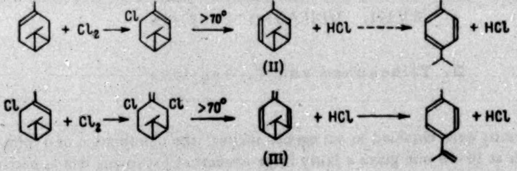
A carefully repeated investigation of the products of thermal breakdown of pinene chlorides (70-80°) showed the absence from them of "dehydroterpenes"; only p-cymene and hydrogen chloride were found.



(I)

Consequently, verbenene (I) is rapidly and quantitatively isomerized to p-cymene under the specified conditions by the action of hydrogen chloride.

The products of thermal decomposition (above 70°) of chlorides of Δ^3- carene included much p-cymene and a small quantity of hydrocarbon with extremely high physical constants (d_4^{20} approx. 0.905, n_D^{20} approx. 1.52). Its analysis corresponded to a formula between $C_{10}H_{12}$, and $C_{10}H_{14}$. Ozonolysis of the hydrocarbon with peroxidation with permanganate gave a small amount of cis-carboxylic acid and a large amount of terephthalic acid. These data alone enabled the hydrocarbon to be identified as a mixture of 2,4-caradiene and p-methylisopropenylbenzene. The former must have been formed from carene monochloride and the latter from allylcarene dichloride.

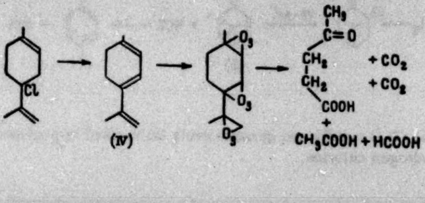


Careful oxidation of this hydrocarbon gave a good yield of α-methyl-α-p-tolylethylene glycol and then of p-methylacetophenone, confirming the presence in the hydrocarbon of p-methylisopropenylbenzene. Since the boiling point of the hydrocarbon is higher than that of p-cymene and much higher than that of carene, the latter could not have been present in the hydrocarbon. The chlorocarene content of the hydrocarbon did not exceed 1.6%; therefore the cis-carboxylic acid formed on ozonolysis could only have originated from 2,4-caradiene (a dehydroterpene).

A special experiment showed that caradiene is formed from the monochloride and methylisopropenylbenzene from the dichloride: the products of chlorination of carene were fractionated in high vacuum at a bath temperature not higher than 70° to give the monochloride and a small amount of dichloride. Distillation of the residue at 20 mm gave methylisopropenylbenzene; under the same conditions the monochloride fraction gave much p-cymene and little "dehydroterpene" with a specific gravity of about 0.90 and a refractive index of about 1.50. Both constants were lowered after redistillation of the "dehydroterpene"; p-cymene was formed, evidently due to isomerization under the action of traces of hydrogen chloride from the incompletely removed monochlorocarene.

These data show that (I) and (III), which contain a hemicyclic double bond, are rapidly isomerized with aromatization of the ring at above 70° in presence of hydrogen chloride, while (II) – which does not contain a hemicyclic double bond – is relatively stable under the same conditions. Verbenene (I) is known; it is isomerized by hydrogen chloride. Compound (III) can only be formed by violation of the Bredt prohibition so that it is unlikely to be stable. Compound (III) is an analog of fulvene and should be colored both in the form of liquid and of vapor. The vapor resulting from distillation of dichlorocarene is colorless, and we can therefore assume that (III) isomerizes in the instant of its formation.

We fractionated the products of chlorination of terpinolene in a fairly high vacuum [9]; the monochloride did not break down. We previously obtained the corresponding "dehydroterpene" [4] by heating terpinolene monochloride with potassium acetate; in the present work the same result was achieved with alcoholic alkali. In both cases HCl was absent; the dehydroterpene was fairly pure so that its structure could be established. Ozonization of the dehydroterpene gave a triozonide, thus confirming the presence of three double bonds, although treatment with excess Br_2 gave a tetrabromide and not a hexabromide. Decomposition of the triozonide with water with permanganate peroxidation gave formic, acetic, carbonic and levulinic acids. Thus we can propose the following scheme for the preparation and structure of the dehydroterpene from terpinolene:



The dehydroterpene can then be assigned the structure of p-menthatriene-1,3,8 (9).

EXPERIMENTAL

Pyrolysis of products of chlorination of α-pinene (D. Tishchenko). 1000 g pinene was chlorinated under the conditions described earlier [1]. The reaction product was freed from excess pinene by distillation in a column at a bath temperature not higher than 50° and a pressure of 1 mm in the column. The residue was distilled at a pressure of 20 mm in the same column; a fraction with b.p. up to 100° was collected and this was refractionated in a column with 7-8 theoretical plates at a reflux number of 12-14 and a pressure of 1 mm. The sole products were p-cymene (d_4^{20} 0.858, n_D^{20} 1.4884, oxidation to p-hydroxyisopropylbenzoic acid) and myrtenol chloride (d_4^{20} 1.013, n_D^{20} 1.4963); verbenene was not detected.

Pyrolysis of products of chlorination of Δ^3-carene (D Tishchenko). 2,400 g carene was chlorinated [6]; the carene was removed as described above. The residue was distilled(20mm);violent evolution of hydrogen chloride took place and the water jet pump could not cope with it; the pressure rose to 28-30 mm. The fraction up to 105° was collected and was fractionated as described above. The products were 620 g p-cymene (d_4^{20} 0.861, n_D^{20} 1.4887, oxidation to p-hydroxypropylbenzoic acid) and 52 g of fractions intermediate between cymene and chlorocarene; also chlorocarene. The intermediate fractions were fractionated in the same column at 10 mm; yield 36 g fraction with b.p. 70-71°.

d_4^{20} 0.904, n_C^{20} 1.5219.

Found %: C 90.4, 90.6; H 10.3, 10.4; Cl 0.3, 0.3. $C_{10}H_{14}$. Calculated %: C 89.55; H 10.45. $C_{10}H_{12}$. Calculated %: C 90.90; H 10.10.

Condensation with maleic anhydride. 5 g of the fraction and 3.8 g anhydride were heated 2 hours in boiling xylene, after which excess of aqueous caustic alkali was added; boiling was continued for an hour and the alkaline layer was removed and made acid to congo. 1.8 g of viscous acid separated. It failed to crystallize. It was dissolved in dry ether and saturated with dry ammonia. The salt was drained at the pump and the salt was dried over potassium hydroxide and analyzed.

Found %: NH_4 11.6. $C_{14}H_{16}O_4(NH_4)_2$. Calculated %: NH_4 12.3.

Ozonolysis of the fraction. 5.2 g of the fraction in 50 ml chloroform was saturated at 0° with 5% ozone. The ozonide was decomposed by stirring with cold water; the chloroform was distilled off from the chloroform layer; the residue was added to the aqueous layer and oxidized at 0° with permanganate until a permanent pink color was formed. The contents of the flask were distilled with steam until the distillate was no longer turbid; the manganese dioxide was then separated, and the filtrate was made alkaline, evaporated to 30 ml and made acid to congo. 0.23 g crystals with m.p. 165-178° was obtained; this was recrystallized from boiling water until the m.p. was constant at 174-176°. Values of 153 and 156 g-equiv. were found; for the cis-carboxylic acid the value found was 79, but it titrates with phenolphthalein like a monobasic acid [10] and gives a value of 158. The steam distillate was extracted with ether; fractionation of the extract gave only one fraction with b.p. 102-104° at 14 mm (2.8 g), d_4^{25} 1.00, n_C^{25} 1.5236. The compound is p-methylacetophenone (see below).

Oxidation of the fraction with permanganate. 20 g of the fraction in 0.5 liter acetone + 25 ml water was oxidized at room temperature and with stirring with dry permanganate (50 g) until a permanent pink color remained; the oxidant was introduced in small portions. The manganese dioxide was filtered off at the pump and washed with acetone. The acetone was distilled from the filtrate in a column,the aqueous residue was extracted with ether, and the extract was fractionated at 13 mm to give the following fractions: 70-102°, 3.5 g; 102-104°, 8.9 g (I); the residue (3 g) crystallized. Fraction (I) had:

d_4^{20} 1.01, n_C^{20} 1.5242.

Found %: C 80.4, 80.7; H 7.5, 7.6. $C_9H_{10}O$. Calculated %: C 80.68; H 7.46.

At 758 mm the b.p. was 224-225°; the oxime (from alcohol) had m.p. 87-88°; the semicarbazone had m.p. 205-206°.* The oxime undergoes the Beckmann rearrangement when heated with a mixture of acetic and sulfuric acids (1:2) on a water bath for 2 hours, and is converted quantitatively into p-acetotoluidine with m.p. 146-147°. No depression in mixed melting test. The compound is p-methylacetophenone.

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* Literature data are not given if already given in Beilstein.

The crystalline residue was recrystallized from gasoline; silky needles with m.p. 39-40°.

Found %: C 72.5, 72.2; H 8.8, 8.9; OH 18.7, 18.4. $C_{10}H_{12}(OH)_2$. Calculated %: C 72.2; H 8.4; OH 20.4.

Careful oxidation of the compound with permanganate gave p-methylisopropyl ketone and α-methyl-α-p-tolylethylene glycol. Energetic oxidation of both the ketone and the glycol leads to terephthalicacid (g-equiv. 66.9, does not melt but sublimes, dimethyl ester with m.p. 141-142°).

The glycol gave hydratropic aldehyde [11] when distilled with 25% sulfuric acid; semicarbazone m.p. 159-160°.

Pyrolysis of 3-chloro-Δ4-carene. 50 g of monochloride (d_4^{20} 1.009, n_C^{20} 1.4989, b.p. 27° at $1 \cdot 10^{-3}$ mm) was distilled in a short column at 20 mm; much HCl came off. The distillate was washed with sodium carbonate solution, dried and fractionated in a column with 6-8 theoretical plates at 13 mm; the following fractions were obtained:

60-63° 12 g, d_4^{20} 0.860, n_C^{20} 1.4852 } p-cymene
63-70°, 6 g, d_4^{20} 0.861, n_C^{20} 1.4878 }
70-83°, 8 g, d_4^{20} 0.935, n_C^{20} 1.5049, % Cl 4.3
83-95°, 11g, d_4^{20} 1.006, n_C^{20} 1.4959, % Cl 19.2.
Residue 8 g

The 70-83° fraction was redistilled in the same column at 3 mm: up to 43° 2.0 g, n_C^{20} 1.4875, d_4^{20} 0.862; 43-50° 4.2 g, n_C^{20} 1.5106, d_4^{20} 0.904, % Cl 0.6.

Pyrolysis of carene polychlorides. Carene and monochlorocarene were distilled off from the product of chlorination of carene in high vacuum (not higher than 0.001 mm) and at a bath temperature not higher than 50°; the pressure was then lowered to $1 \cdot 10^{-4}$ mm and a small portion (d_4^{20} 1.11) was distilled off; the residue thus did not contain chlorocarene. 40 g of residue was fractionated in a column with a Vigreux condenser at 20 mm; HCl came off; the first drops came over at 76°; up to 100° 5.6 g came over, n_C^{20} 1.5120. Redistillation at 10 mm gave 4 g of fraction with b.p. 70-73°, n_C^{20} 1.5203, d_4^{20} 0.903.

Dehydroterpene from terpinolene (IV) (T. Danilova). Prepared by heating 4-chlorodipentene [9] with alcoholic alkali. Fractionation of the reaction product (a little hydroquinone was added) in a column of 4-5 theoretical plates at 2 mm gave a fraction with b.p. 46-48°, d_4^{20} 0.885, n_D^{20} 1.5222. M in benzene: found 137; $C_{10}H_{14}$ requires 134. Kaufmann bromination gave 2.1 and 2.04 double bonds.

To the cooled mixture (-20°) of 1.25 g dehydroterpene, 1.5 ml methanol and 3 ml dry ether was added bromine (dropwise) until the color persisted, after which the solvent was removed in vacuum and the solid residue was recrystallized from dry ether until the m.p. was unchanged at 131-132°. The mixture with dipentene tetrabromide (m.p. 125-127°) melted at 119-121°.

Found %: Br 70.1, 70.4, $C_{10}H_{14}Br_4$. Calculated %: Br 70.12. In mesitylene solution MR_D found was 77.01; value calculated for $C_{10}H_{14}Br_4$ was 76.77.

The tetrabromide contains a double bond.

Ozonolysis. 5 g of the hydrocarbon in 50 ml chloroform at -20° was saturated with ozone until it gave a negative reaction with bromine (125 liters of 5% ozone). In spite of the cooling it was necessary to make two additions of chloroform; part of the hydrocarbon also evaporated. The chloroform was removed from one-tenth of the solution in vacuum; the ozonide was analyzed.

Found %: C 44.0, 44.7; H 6.5, 6.6. $C_{10}H_{14}O_6$ (diozonide). Calculated %: C 52.1; H 6.1. $C_{10}H_{14}O_9$ (triozonide). Calculated %: C 43.2; H 5.1.

The chloroform solution of the ozonide was stirred 3 hours with 150 ml cold water and then oxidized by addition of 2% permanganate solution. The manganese dioxide was removed and the aqueous layer was neutralized, evaporated to 50 ml, made acid to congo and distilled with steam until the distillate was neutral. The neutralized distillate was evaporated to 100 ml and a portion of it was precipitated with the calculated amount of silver nitrate. The rapidly blackening (formic acid) precipitate was recrystallized from hot water to give needles of silver acetate (% Ag 64.9). The aqueous solution in the distillation flask was evaporated to dryness in vacuum and the residue extracted with ether. The ether was driven off from the extract; the residue (2.5 g) came over amost completely at 115-120° and 3 mm. Viscous liquid; found g-equiv. 121 and 122; $C_5H_8O_3$ (levulinic acid) requires 116. The silver salt was ignited.

Found %: C 26.1, 26.1; H 3.4, 3.4; Ag 48.4, 48.1. $C_5H_7O_3Ag$. Calculated %: C 26.9; H 3.1; Ag 48.4.

The phenylhydrazone of the acid, recrystallized from benzene, had m.p. 108°. The compound is levulinic acid.

SUMMARY

1. Systematic data are presented for the "dehydroterpenes" that we prepared; these are hydrocarbons with the empirical formula $C_{10}H_{14}$ which are isomeric with p-cymene but do not belong to the aromatic series.

2. It is shown that they can be obtained either by pyrolysis of chloroterpenes or by removal from the latter of the elements of hydrogen chloride. The dehydroterpene from Δ^3- carene corresponds to 2,4- caradiene in structure; that from terpinolene to p-menthatriene-1,3,8 (9).

3. Pyrolysis of dichlorocarene gives a still more unsaturated hydrocarbon $C_{10}H_{12}$ which is identified as p-methylisopropenylbenzene.

4. Dehydroterpenes are found to be stable in absence of inorganic acids.

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A NEW TYPE OF TRANSFORMATION OF TERPENES

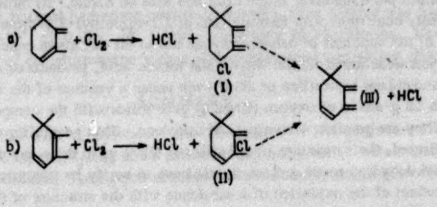
XIX. THE ACTION OF CHLORINE ON β-PYRONENE

D. Tishchenko and N. Summ

In one of the preceding communications we described [1] the reaction of chlorine with α-terpinene, a terpene containing a system of conjugated double bonds. This reaction led to formation of p-cymene and 1,4-dichloro-2-menthene. We later established [2] that conjugated dienes of the aliphatic series with central or terminal perturbation of the conjugation react anomalously (the M.D. Lvov reaction) with formation of chlorodienes of the allyl type with a translocated double bond. This provides considerable further support for our theory that formation of p-cymene during chlorination of α-terpinene involves an allyl rearrangement of the initially formed 2-chloro-p-menthadiene-3,6 to 6-chloro-p-menthadiene-1,3 which then splits off hydrogen chloride. The driving force of this transformation is the energy released during aromatization of the dihydrobenzenic ring of chloromenthadiene to the benzenic ring of p-cymene (+22 kcal/mole). These two investigations revealed a fresh exception to the Thiele rule, but the case of α-terpinene is not too convincing because of the instability of chloromenthadiene. It was therefore desirable to confirm the inapplicability of the Thiele rule to the chlorination of terpenes containing a conjugated system of double bonds by means of some other example with exclusion of the dienic chloroterpene.

With this objective we undertook a study of the action of chlorine on β-pyronene under the conditions that we have repeatedly described [3]. This substance, as we recently showed [4], is a mixture of 1,1-dimethyl-2-methylene 3-methylcyclohexene-3 and 1,1,2,3-tetramethylcyclohexadiene-2,4 with the former predominating. The presence of a gem-dimethyl group in the ring of these terpenes excludes the possibility of aromatization of the ring, so that the formation of a monochloroterpene can be expected.

According to our previously developed considerations [5], these terpenes must react with chlorine in the following manner:



Only the Δ^3 bond in terpene a can react with chlorine anomalously, since there are no hydrogen atoms in the α-position to the heptacyclic ring. If the chloroterpene (I) were unstable, the removal of hydrogen chloride from it should give the "dehydroterpene" (III). In terpene b the Δ^2 bond will react anomalously with preferential formation of chloroterpene (II). Chloroterpenes (I) and (II) will give one and the same "dehydroterpene" (III) in the event of loss of hydrogen chloride.

Chlorination of " β - pyronene " was effected under the usual conditions [3]. The course of this reaction is closer to the chlorination of α-terpinene than it is in the case of other compounds (pinenes, carene, camphene, etc.), judging by the considerable heat development. In spite of cooling of the reaction mixture with ice and salt, it was necessary to introduce the chlorine slowly to avoid undesirable overheating. The yields of the "anomalous" reaction fluctuated by about 100 % (determination on the basis of the amount of chlorine going into formation of hydrochloric acid). Polychloro derivatives are also found on fractional distillation. Consequently the analytically determined yield of the "anomalous" reaction is, at any rate in part, the reflection of the partial breakdown of the monochloroterpene to dehydroterpene and hydrogen chloride. During fractional distillation of the reaction product, unchanged " β -pyronene " first came over; this was followed by fractions with specific gravity of 0.93-0.95 and refractive indices of 1.51-1.53. The picture was not altered by distillation of the reaction product at any pressure down to $1 \cdot 10^{-4}$ mm. After the fractions in question had been taken off, the boiling point rose rapidly and the compound that distilled over corresponded in composition and constants to a dichloro derivative.

Rectification of these fractions at 0.001 mm in a column with an efficiency of about 20 theoretical plates gives a small head fraction with constants corresponding to dehydroterpene $C_{10}H_{14}$; also a series of fractions with relatively unchanged constants intermediate between those possible for dehydroterpene and monochloroterpene (b.p. 27-29°, d_4^{20} 0.94-0.95, n_D^{20} 1.514-1.515, % Cl 11-13). We must assume that dehydroterpene and chloroterpene in this ratio (approximately equimolar) form an azeotrope. All the chlorine is mobile; consequently the chloroterpene is of the allyl type. Distillation of the reaction product in the vacuum specified is not accompanied by release of hydrogen chloride; this implies that the monochloroterpene is fairly stable and that dehydroterpene is formed during chlorination, as is also indicated by the yield of the "anomalous" reaction (see above).

These data demonstrate the inapplicability of the Thiele rule to the reaction of chlorine with "β -pyronene", a mixture of two monocyclic terpenes which are 1,3-dienes with central and terminal perturbation. The results also confirm the correctness of our ideas about the chlorination of α-terpinene [1]. However, the inability to obtain the pure monochloro compound prevented us from determining its structure and of showing the applicability to the case of " β -pyronene " of our proposed mechanism of the chlorination of conjugated terpenes. We planned to react sodium butoxide with the azeotrope and so transform the chloroterpene into terpinyl butyl ether which boils much higher than chloroterpene, to fractionate the dehydroterpene and the ether, and to determine the structure of the ether; in this way we hoped to obtain some data for the structure of the chloro compound. It was found, however, that hydrogen chloride was split off, and we obtained pure dehydroterpene with b.p. 29-30° at 0.06 mm, d_4^{20} 0.905, n_D^{20} 1.5185, MR_D found 44.9; % C 89.2; H 10.5; calculated for $C_{10}H_{14}3F$: MR_D 44.9%; % C 89.5; H 10.5. The hydrocarbon is transformed into a very viscous polymer, slowly on standing in a sealed tube and rapidly when heated. This polymer has specific gravity 0.90 and n_D^{20} 1.4812, which indicates the presence of conjugated double bonds; however, it does not condense with maleic anhydride on boiling in benzene solution and it does not react with bromine in diffuse light, whereas it is rapidly oxidized by a solution of potassium permanganate in the cold and adds on ozone. Its molecular refraction is not exalted. All these facts are hardly consistent with formula (III) of 1,1-dimethyl-2,3-dimethylenecyclohexene-4 given above. Investigation of the structure of dehydroterpene has so far not given conclusive results. Among the products of its ozonolysis were found formaldehyde and formic acid, products of an acid character which were nonvolatile in steam and did not crystallize or distil even under a vacuum of the order of $1 \cdot 10^{-5}$ mm. Oxidation of dehydroterpene with 12 g-atoms of oxygen ($KMnO_4$) gave solids with the compositions $C_8H_6O_4$ to $C_8H_6O_6$ which were not aromatic. They are possibly derivatives of tropolone. This possibility requires special investigation. Even if this were confirmed, their structure would still not allow us to draw any direct conclusions about the structure of the original dehydroterpene and we should have to verify its structure by some other independent route. The normal product of the oxidation of a substance with the structure of (III) must be asymmetric dimethylsuccinic acid, but this was not obtained. Tropolene carboxylic acids and hydroxytropolone carboxylic acids of the indicated composition can only be prepared by an "abnormal" course of oxidation, but the mechanism of the oxidation can only be elucidated if we know the structure of the dehydroterpene.

EXPERIMENTAL

Chlorination of "β-pyronene". Pyronene was prepared by thermal isomerization of alloocimene [6]; its constants were the same as those in the literature. Chlorination was performed under the previously described conditions [7] while cooling with ice and salt. The yield of the "anomalous" reaction in three runs fluctuated around 100%.

Data for fractional distillation of the products of chlorination from one of the experiments (218.5 g) in a column with 6-7 theoretical plates (reflux number 8-10), dephlegmator pressure 1.5 mm) are presented below.

Fraction number	Bath temperature	Vapor temperature	Weight (g)	d_4^{20}	n_D^{20}
1	64°	31—[illegible]	102	0.8435	1.4776
2	70	33—40	2.2	0.875	1.4827
3	80	40—54	4.2	0.893	1.4951
4	96	54—60	39.3	0.949	1.5127
Residue			60.5		
Losses			10.3		

25.5 g was distilled off from the residue at a pressure of 0.001 mm, a bath temperature up to 100° and a vapor temperature of 31-50°. The residue had d_4^{20} 1.142 and contained 34% chlorine; it was therefore free of monochloro compound (% Cl 20.7, specific gravity about 1.0). The 25.5 g was fractionated at 1 mm to give a 52-56° fraction (13.5g) with d_4^{20} 0.953. The specific gravity of the new residue (11 g) was 1.106. A fresh fractionation of the combined fractions with specific gravity of about 0.95 in a column with an efficiency of about 20 theoretical plates, at a pressure of about 0.001 mm in the dephlegmator, gave two fractions:

1st, b.p. 27-27.5°, 20g, d_4^{20} 0.953, n_D^{20} 1.5142, % Cl 11.2; 2nd, b.p. 27.5-28°, 22 g d_4^{20} 0.950, n_D^{20} 1.5161, % Cl 10.7.

Heating of the azeotrope with sodium butoxide. 39.5 g azeotrope was heated with a solution of 4 g sodium in 200 ml butanol under a reflux condenser on a boiling water bath for 6 hours. 7.5 g NaCl was obtained; the reaction went to completion. Butanol was removed from the reaction product by washing with water until the volume of the oily layer was constant. The dry oil weighed 33 g. On distillation in a small column (pressure 0.06 mm) the main fraction came over at 29-30 mm (for constants and analysis see the general part) The residue contained a viscous polymer.

Azeotropic separation of dehydroterpene from chloropyronene. 44 g "β-pyronene" was chlorinated under the usual conditions and the excess pyronene was distilled off from the reaction product. Into the residue was run 70 ml butanol, and the mixture was fractionated at 14 mm in a column with 6-8 theoretical plates (reflux number 15) until all the butanol had come over (b.p. 30-35°). The residue was fractionated at 0.1 mm to give a fraction with b.p. 72-73°, d_4^{20} 0.998, n_D^{20} 1.5008, containing 15.9% chlorine. Normal fractionation had earlier given an azeotrope of dehydroterpene with a chloro compound containing about 11% chlorine.

SUMMARY

1. The reaction of chlorine with "β-pyronene" was investigated. The products of reaction are, apart from polychlorides, the dehydroterpene $C_{10}H_{14}$ and a monochloroterpene which were separated in the form of an azeotrope on fractional distillation. Formation of monochloroterpene demonstrates the inapplicability of the Thiele rule in this case.

2. Treatment of monochloroterpene with sodium butoxide gives dehydroterpene. The latter has very unusual physical and chemical properties.

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CATALYTIC HYDROGENATION OF MENTHENE OXIDES

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The addition of hydrogen to α-oxides opens up the possibility of passage from unsaturated hydrocarbons to monohydric alcohols. The literature on the catalytic hydrogenation of oxides shows that the reaction goes fairly smoothly in a number of cases and leads to the corresponding hydroxyl-containing compounds. Hydrogenation is effected with facility, for example, in the case of ethyl esters of oxides of unsaturated higher fatty acids (in presence of Pd black in alcoholic solution), on the basis of which a new method of preparation of hydroxy acids was developed, starting from esters of unsaturated acids [1]. α-Ketoxides of the fatty-aromatic and aromatic series [2,3] and α-ketoxides of the terpene series [4] are likewise fairly easily hydrogenated. Finally, the patent literature [5] reports hydrogenation under mild conditions of Δ^3-menthene oxide with formation of menthol. Some oxides, however, are hydrogenated with difficulty or do not combine with hydrogen at all even in presence of extremely active catalysts. In isolated cases, when hydrogenation of the oxides can be effected under more drastic conditions, it is accompanied by secondary reactions with formation of a fairly complex mixture of products.

Our aim was to pass from terpene hydrocarbons to cyclic alcohols of the terpene series via the oxides, and to elucidate the stereochemical relations during this transition.

The compounds selected for investigation were Δ^1-menthene oxide (carvomenthene) and trans-Δ^2-menthene oxide. We are the first to characterize the former oxide in detail because the literature [6] only refers to its conjectured formation as a secondary product in the oxidation of carvomenthene with selenous acid (the main product of this reaction is carvotanacetone). Δ^3- Menthene oxide was also prepared for comparative hydrogenation experiments.

Δ^2-Menthene oxide and carvomenthene oxide were prepared by direct oxidation of the corresponding hydrocarbons with perbenzoic acid by Prilezhaev's method [7]. For the preparation of Δ^3-menthene oxide we resorted to partial oxidation with perbenzoic acid of the mixture of Δ^3- and Δ^2-menthenes obtained on thermal breakdown of the methyl ester of menthylxanthic acid. Only Δ^3-menthene undergoes oxidation when there is a deficiency of perbenzoic acid.

The physical constants of the menthene oxides are presented in Table 1.

TABLE 1
Physical Constants of Menthene Oxides

	Carvomenthene oxide	Δ^2-Menthene oxide	Δ^3-Menthene oxide
Boiling point	66.5—66.7° (at 7 mm)	74—75° (at 10 mm)	69—70.5° (at 11 mm)
d_4^{20}	0.9059	0.9065	0.8928
n_D^{20}	1.4509	1.4512	1.4438
α_D	+52.12°	+42.80°	+51.76°
$[\alpha]_D$ . . .	+57.53°	+47.21°	+57.97°
MR_D * . .	45.84	45.83	45.87

*Calculated by Zimakov's method [10] with allowance for the atomic refraction of oxygen in the heterocyclic grouping (1.074) and for the increment of the 3-membered ring (+0.7), the value of MR_D is 45.75.

The data for Δ^2-menthene oxide agree with those in the literature [8]. Our preparation of Δ^3-menthene oxide differed from all previously described preparations of this substance [9] by its high optical activity. This fact points to the absence from it of Δ^2-menthene oxide which is a common impurity. We characterized all the oxides that we investigated by the Raman spectra (see below).

For the hydrogenation of menthene oxides we tried out several common laboratory catalysts in conjunction with various solvents. We used Δ^2-menthene oxide in the majority of the experiments aimed at selecting the conditions of hydrogenation. Pt black, platinum oxide, Raney nickel, Pd black and palladium oxide were tested in addition to palladium-on-nickel [11] and palladium hydroxide-on-calcium carbonate [12]. None of these catalysts gave sufficiently satisfactory results: either no hydrogen was absorbed or only partial absorption occurred. The maximum absorption of hydrogen (about 80%) by Δ^2-menthene oxide with catalysts of the above type was observed with Pd black and palladium oxide in acetic acid.

We were unfortunately unable to repeat the hydrogenation of the menthene oxides under the conditions specified in the patent literature [5]. The authors of the patent hydrogenated Δ^3-menthene oxide in presence of colloidal palladium in methanol solution. We failed, however, to find any information in the literature about the preparation of such a catalyst. Moreover, attempts to employ colloidal palladium in other solvents such as aqueous acetone [13] and acetic acid [14] did not give the desired results.

For the preparation of a colloidal solution of palladium in acetic acid we made use of palladium hydrate precipitated by treatment of palladium chloride solution with sodium carbonate. According to the work of Piccard and Thomas [14] the $Pd(OH)_2$ precipitated in this manner can be dissolved in acetic acid, and passage of hydrogen through the solution leads to formation of a colloidal solution of metallic palladium (without any protective colloid). Coagulation of the palladium may occur only on completion of the process of hydrogenation of the organic substance.

Since the cited paper [14] does not give experimental details, we tried to establish the conditions of preparation of palladium hydroxide in a form capable of dissolving in acetic acid. Various methods of precipitation of $Pd(OH)_2$ were tried , and it was found that regardless of the method of precipitation the only precipitates soluble in glacial acetic acid were those that had not been subjected to drying. On the other hand, dried precipitates of $Pd(OH)_2$ (dried in the air, in a vacuum-desiccator or in a thermostat at 110°) were almost insoluble in acetic acid. Nevertheless, hydrogenation experiments with such precipitates showed that palladium hydroxide prepared in this manner was actually a suitable catalyst for the hydrogenation of menthene oxides in acetic acid solutions.

Menthene oxides were not hydrogenated or only incompletely hydrogenated in presence of solutions prepared by dissolving the freshly precipitated, still wet, palladium hydroxides in acetic acid. When these acetic acid solutions were shaken with hydrogen (in the presence or absence of the menthene oxide), we observed (contrary to the statement of Piccard and Thomas) immediate separation of coagulated palladium, and the solutions became perfectly transparent.

The new catalyst that we prepared – $Pd(OH)_2$ without a carrier – can be confidently recommended in a number of cases in place of the classical hydrogenation catalysts (Pd-black and palladium oxide). Its preparation is considerably simpler than that of the other catalysts mentioned; it does not call for special equipment or relatively costly reagents and the procedure for preparation gives consistently good results.

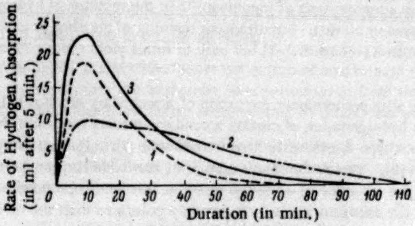
TABLE 2

Hydrogenation of Menthene Oxides in presence of Palladium Hydroxide (without a carrier)

Solvent	% Hydrogen absorbed by		
	carbomenthene oxide	Δ^2-menthene oxide	Δ^3-menthene oxide
Without solvent	0	–	–
Ether	–	0	–
Ethyl alcohol	48	29	12
Methyl alcohol	67	0	0
Acetic acid	90	110	131

Hydrogenation of unsaturated compounds (e.g menthenes) with this catalyst goes smoothly in alcohol or in methanol solution, but for menthene oxides it is necessary to use acetic acid as the solvent. As we see from the data of Table 2, hydrogenation of menthene oxides in other solvents or without a solvent only goes incompletely or not at all.

In presence of palladium hydroxide in acetic acid the absorption of hydrogen by Δ^3-menthene and Δ^2-menthene oxides considerably exceeds 100%. On the other hand the hydrogenation of carvomenthene, judged by the hydrogen absorption under these conditions, does not go to completion. Comparative experiments carried out simultaneously showed (Fig. 1) that Δ^3-menthene oxide has the highest rate of hydrogenation. Carvomenthene oxide absorbs hydrogen rather more slowly, although the course of the curve is similar. Δ^2-Menthene oxide has the lowest hydrogenation velocity but the process is more uniform.



Comparative hydrogenation of menthene oxides

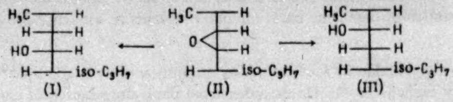
A detailed examination of the products of hydrogenation of Δ^2-menthene oxide and carvomenthene oxide showed that this reaction proceeds far from smoothly under the specified conditions. The normal products of hydrogenation (terpenic alcohols) are accompanied by large amounts of other substances. This is particularly the case with carvomenthene oxide (Table 3).

TABLE 3

Approximate Composition of Products of Hydrogenation of Menthene Oxides (in %).

	Carbomenthene oxide	Δ^2-Menthene oxide
Alcohols	33	78
Hydrocarbons	18	10
Ketones	28	5
Resinous residue after distillation	21	7

The main reaction during hydrogenation of Δ^2-menthene oxide (the formation of alcohols) is accompanied by opening of the oxide ring in both of the possible directions, due to which menthanol-3 (L-menthol) and menthanol-2 (D-neocarvomenthol) are formed in approximately equal proportions. The fact that L-menthol (I) and D-neocarvomenthol (III)are actually formed (these two compounds are genetically related) and not other stereoisomers of menthanol-3 and menthanol-2 compels us to assume that the trans-Δ^2-menthene oxide, (II) which served as starting substance, was one of the two possible stereoisomers of the oxide. Such an assumption can be made by analogy with the existence of the so-called stereoisomeric α- and β-oxides in the steroid series; it is known that in some cases only one of these stereoisomers is formed [15]. With the help of projection formulas the hydrogenation of trans-Δ^2-menthene oxide can be represented by the following scheme: *



In contrast to Δ^2-menthene oxide, the hydrogenation of carvomenthene oxide is accompanied by rupture of the oxide ring predominantly in one direction with formation of a secondary alcohol – menthanol-2. Among the products of hydrogenation were found its two stereoisomers (L-carvomenthol and D-neocarvomenthol). The latter was found to be identical with the D-neocarvomenthol formed on hydrogenation of Δ^2-menthene oxide. The total content of both stereoisomers of menthanol-2 in the mixture of hydrogenation products was 26 %, the D-neocarvomenthol predominating. Simultaneous opening of the ring in another direction leads in the present case to a tertiary alcohol (menthanol-1) but only in small yield (about 7% of the total products of hydrogenation).

Opening of the oxide ring with predominant formation of a secondary alcohol is in agreement with the literature data for the catalytic hydrogenation of certain secondary-tertiary oxides of the cyclohexane series [4, 5, 17]. An ion of the oxonium type is evidently here formed with participation of hydrogen which is protonized by the palladium catalyst [3]. The predominant rupture of the oxide ring at the tertiary carbon atom in the present case is governed by the presence of a methyl group at this atom; the bond between the tertiary carbon atom and the oxygen in the oxonium ion is more strongly polarized than the other C-O bond and is therefore less stable [18].

The reason for the formation during hydrogenation of carvomenthene oxide of the stereoisomers of menthanol-2 that we found among the products of hydrogenation (D-neocarvomenthol and L-carvomenthol) is more complex. Their joint presence evidently points to the original carvomenthene oxide being (unlike Δ^2-menthene oxide) stereochemically heterogeneous and a mixture of two stereoisomers.

The hydrogenation of menthene oxides under our conditions leads, as mentioned above, to a number of secondary products in addition to the main products (alcohols). In the course of hydrogenation a fairly large amount of hydrogen is consumed in a more far-reaching reduction which leads to complete elimination of oxygen with formation of menthane. This accounts for the observation that, in spite of the low yield of alcohols (Table 3), the amount of hydrogen absorbed during hydrogenation of carvomenthene oxide in acetic acid is approximately theoetical, while in the hydrogenation of Δ^2-menthene oxide it even exceeds the amount theoretically required for reduction of the oxide to the corresponding alcohols. In the case of Δ^3-menthene oxide, judging by the amount of absorbed hydrogen (Table 2), the elimination of oxygen under the same conditions takes place to an even greater extent. Similar results were obtained by Kotz and Busch [9] in the hydrogenation of Δ^3-menthene oxide in acetic acid solution in presence of palladium-on-animal charcoal.** Other examples of such an elimination of oxygen with formation of saturated compounds during hydrogenation of oxides, especially in an acetic acid medium, have been frequently reported [4, 19].

More unexpected is the process of isomerization of the oxides to ketones, which takes place, as we found, under the conditions of hydrogenation. A particularly large amount of ketones (carvones and, in part, isocarvomenthone) is formed during the hydrogenation of carvomenthene oxide (Table 3). There is a fairly extensive literature on the isomerization of α-oxides to carbonyl-containing compounds when heated or under the action of inorganic acids [20]. At ordinary temperatures, however, this type of transformation does not generally take place under the influence of acetic acid unless we take into account the possibility of such an isomerization as that proposed in the case of oxides of fatty acids [21].

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* It is known that the change of configuration on rupture of the oxide ring could only take place at the C-atom at which the bond with the oxygen was broken [16]. In the case, however, of Δ^2- menthene oxide there are two hydrogen atoms at the C-atom in question, so that the problem of the change of configuration does not arise. In this case, therefore, the configuration of the alcohols is entirely governed by the spatial structure of the original oxide.

** It must be pointed out, however, that these authors did not use pure Δ^3-menthene oxide in their experiments and that the menthane obtained on hydrogenation of this oxide possessed a high optical activity (α_D + 46.62°), whereas this hydrocarbon cannot normally be optically active. Some reserve must therefore be expressed about the results of Kotz and Busch.

We instituted several special experiments to clarify the action of acetic acid on carvomenthene oxide under the conditions of catalytic hydrogenation. These experiments showed that in the absence of a catalyst in the cold, acetic acid causes partial transformation (slight heat is developed) into the monoacetate of menthanediol-1,2. In presence of palladium, obtained by reduction of palladium hydroxide, however, the main reaction becomes isomerization of carvomenthene oxide to carvomenthone.

We also attempted to elucidate the mechanism of hydrogenation of the oxides by carrying out experiments on the hydrogenation of the corresponding ketones (carvomenthone and menthone). As was to be expected, the ketones failed to absorb hydrogen under our conditions for hydrogenation of the oxides. Consequently the isomerization of the oxides to ketones which occurs in presence of palladium catalyst in acetic acid actually hinders their hydrogenation: transformation into ketone causes part of the oxide to be withdrawn from the sphere of reaction and that part is no longer able to furnish alcohols.

Similarly, part of the oxide is converted under the action of acetic acid (especially in the case of carbomenthene oxide) into a glycol acetate and is thereby likewise removed from the sphere of reaction. Hydrogenation of oxides under our conditions is evidently accompanied by other, less well-marked processes.

In the course of investigation of the products of hydrogenation of Δ^2- menthene oxide and carvomenthene oxide, we plotted the Raman spectra of these products. These spectra were utilized for characterization of the products and in part for their identification.

EXPERIMENTAL

Δ^2-Menthene oxide. A solution of 83 g Δ^2-menthene [8] in an equal colume of chloroform was added portionwise with cooling to 1520 ml chloroform solution containing 93 g perbenzoic acid[*] (11% excess of oxidant). The temperature of the reaction mixture did not exceed + 10°. Completion of oxidation was confirmed the following day by iodometric titration. The reaction mixture was washed with KOH solution and with water and dried with potassium carbonate. The chloroform was then distilled off. Distillation in vacuum gave 88 g of Δ^2-menthene oxide (94.5 %).

Found %: C 77.61, 77.42; H 11.88, 11.82; O (oxidic: by titration by King's method [22]) 10.14, 10.16. M. 153.3, 155.0. $C_{10}H_{18}O$. Calculated %: C 77.86; H 11.76; O (oxidic) 10.37. M 154.2.

Raman spectrum: $\Delta\nu$ 281 (1), 310 (3), 345 (1), 387 (1), 419 (2), 447 (4), 501 (?), 518 (?), 584 (1), 630 (2), 694 (1), 754 (10), 792 (3), 811 (2), 843 (3), 871 (3), 933 (3), 955 (3), 985 (1), 999 (2), 1029 (?), 1044 (5), 1100 (5), 1133 (1), 1157 (3), 1214 (4), 1256 (5), 1295 (1), 1336—1350 (3), 1386 (1), 1447—1461 (9), 2873 (7), 2931 (3), 2966 (4).

Carvomenthene oxide. A mixture of 105.5 g carvomenthene and 9.1 g menthane, prepared by partial hydrogenation of limonene in presence of Pt-black [24], diluted with twice the volume of chloroform, was run portionwise into 1480 ml solution of perbenzoic acid (114 g) in chloroform (8% excess of oxidant). The mixture was worked up as before. Three distillations in vacuum gave 100 g carvomenthene oxide (80% reckoned on the carvomenthene in the original mixture).

Found %: C 77.84, 77.71; H 11.87, 11.76, M 153.3, 152.2. $C_{10}H_{18}O$. Calculated %: C 77.86; H 11.76. M 154.2.

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[*] The perbenzoic acid solution was prepared by Smit's method [23]. The method of preparation of the benzoyl peroxide [7] needed for preparation of perbenzoic acid was modified in order to make the synthesis of the preparation more convenient and reliable: to a rapidly stirred (mechanically) aqueous solution of sodium peroxide was added dropwise not pure benzoyl chloride but its mixture with an equal volume of ether. At this dilution the drops of benzoyl chloride did not tend to fall rapidly to the bottom of the vessel and were able to react completely even with not fully efficient working of the stirrer. In addition the benzoyl peroxide separates from the ethereal solution in the form of crystals (and not in the form of amorphous grains), i.e. in a purer state. Yield 80%.

Raman spectrum: $\Delta\nu$ 237 (2), 269 (2), 299 (3), 342 (1), 391—411 (1), 453—467 (1), 493 (3), 525 (1), 550 (2), 675 (10), 756 (9), 789 (3), 840 (5), 865 (4), 896 (4), 919 (1), 953 (4), 983 (1), 1016 (2), 1043 (6), 1095 (1), 1120 (1), 1147 (3), 1197 (2), 1210 (2), 1252 (2), 1280 (1), 1304 (6), 1328 (1), 1358 (3), 1373 (3), 1424—1463 (7), 2868 (7 b), 2920 (7 b), 2967 (7 b).

Δ^3-Menthene oxide. A mixture of menthenes, prepared by Chugaev's method [25] (65.5 g, α_D + 95.08°), containing 72% Δ^3-menthene and 28% Δ^2-menthene (determined by racemization of the Δ^3-menthene with p-toluenesulfonic acid [8,26]), was diluted with an equal volume of chloroform. Dropwise addition was made to this mixture of 582 ml chloroform solution containing 40 g perbenzoic acid (59% of the quantity needed for oxidation of both menthenes). After working up in the usual manner and 2 distillations in vacuum, 36.5 g Δ^3-menthene oxide was obtained (82% reckoned on the perbenzoic acid).

Found %: C 77.61, 77.39; H 11.84, 11.72. $C_{10}H_{18}O$. Calculated %: C 77.86; H 11.76.

Raman spectrum: $\Delta\nu$ 225 (?), 286 (3), 311 (?), 365 (3), 426 (3), 481 (1), 500 (2), 564 (1), 641 (3), 669 (2), 696 (5 b), 760 (6 b), 790 (5), 815 (1), 850 (4), 864 (4), 908 (1), 977 (?), 992 (1), 1022 (?), 1044 (5), 1092 (3), 1124 (2), 1155 (1), 1180 (1), 1217 (2), 1259 (1), 1278 (1), 1308 (3), 1337 (1), 1356 (2), 1426 (4), 1450—1460 (9).

The mixture of hydrocarbons that did not enter into the oxidation reaction (b.p. 56-58° at 18 mm, α_D + 102.28°) consisted, judging by racemization data [8, 26], of 13% Δ^3-menthene and 87% Δ^2-menthene. In the spectrum of this mixture the ratio of intensities of the lines of the double bonds ($\Delta\nu$ 1667 and 1643 cm^{-1}) was 1:10.

Palladium hydroxide. 5 g of palladium chloride was dissolved with gentle heating in 250 ml water containing 5 ml conc. HCl. To the mixture, cooled to room temperature, was gradually added a saturated solution of sodium carbonate until definitely alkaline to phenolphthalein. The resultant dark-brown solution was heated for 6 hours at 60-70° and stood overnight. The precipitate of $Pd(OH)_2$ was collected, washed on the filter with water (until the wash water had a negative reaction for OH' and Cl' ions) and dried. The dense, dark-brown pellets of $Pd(OH)_2$ were pulverized and screened (diameter of holes 0.25 mm). Yield 3.9 g (97%).

Hydrogenation of Δ^3-menthene oxide. 5 g $Pd(OH)_2$ and 10 ml acetic acid were shaken with hydrogen for 1 hour. Δ^3-Menthene oxide (15.1 g) was then introduced into the flask in a current of hydrogen. Hydrogenation was accompanied by appreciable heating of the flask and was completed in $1^1/_2$ hours after absorption of 2500 ml (calcd. 2330 ml) hydrogen. Another 5 portions of Δ^3-menthene oxide were hydrogenated with the same batch of catalyst. Hydrogen absorption on the average amounted to 111%.

The combined acetic acid solutions of the products of hydrogenation were diluted with double the volume of water. The oily layer was separated, and the aqueous layer was subjected to salting-out with sodium acetate and then twice extracted with ether. The ethereal solution of the products of hydrogenation were neutralized with saturated sodium carbonate solution, washed with water and dried with potassium carbonate. The ether was driven off. The following fractions were obtained after careful and repeated fractionation in vacuum in a column (6 theoretical plates):

1. L-Menthol fraction.

B.p. 98.5-99°(at 10.5 mm), d_4^{20} 0.9019, n_D^{20} 1.4616, α_D −31.00°, $[\alpha]_D$ −34.37°, MR_D 47.59 (calc. 47.60).

Literature data for L-menthol [27]: B.p. 216°, d_{15}^{15} 0.904, n_D^{20} 1.4609, $[\alpha]_D$ - 49.4°.

Found %: C 76.80, 76.82; H 12.93, 12.93; OH 11.87. M 160.1, 165.8. $C_{10}H_{20}O$. Calculated %: C 76.86; H 12.90; OH 10.89. M 156.3.

Raman spectrum: $\Delta\nu$ 254 (1), 293 (1), 407 (1), 424 (1), 467 (1), 491 (?), 504 (1), 546 (3), 596 (1), 768 (10), 797 (?), 805 (2), 849 (1), 873 (2), 920 (2), 959 (?), 1019 (1), 1044 (2), 1101 (2), 1146 (3), 1177 (4), 1242 (1), 1268 (1), 1306 (1), 1343—1360 (3), 1371 (1), 1446—1460 (8), 2864 (4 b), 2933 (4 b). 2960 (2).

The spectrum is identical with that of natural L-menthol that we plotted, and also with that described in the literature [28].

The 3,5-dinitrobenzoate, prepared from the L-menthol fraction, had m.p. 152.5-153° (from alcohol) and melted without depression of melting point when mixed with the 3,5-dinitrobenzoate of natural L-menthol. According to the literature [27] the 3,5-dinitrobenzoate of L-menthol melts at 153°.

2. D-Neocarvomenthol fraction.

B.p. 96.5-97° (at 13 mm), d_4^{20} 0.9021, n_D^{20} 1.4609, α_D + 22.96°, $[\alpha]_D$ +25.45°, MR_D 47.52 (calc. 47.60).

Literature data for L-neocarvomenthol [27]: b.p. 96°(at 11 mm), d_4^{20} 0.9012, n_D^{20} 1.4644, $[\alpha]_D$-42°.

Found %: C 76.33, 76.41; H 12.74, 12.73; OH 10.25, 10.95. M 163.5. $C_{10}H_{20}O$. Calculated %: C 76.86; H 12.90; OH 10.89. M 156.3.

Raman spectrum:

Δν 289 (1), 311 (3), 359 (1), 407 (1), 447 (1), 493 (1), 505 (?), 520 (?), 546 (1), 585 (1), 609 (?), 754 (10), 795 (1), 844 (2), 858 (?), 882 (?), 932 (1), 956 (3), 993 (1), 1034 (2), 1065 (3), 1099 (1), 1128 (1), 1145 (2), 1193 (2), 1219 (1), 1252 (4), 1315 (3), 1357 (3), 1448—1462 (10), 2869 (8 b), 2926 (5 b), 2963 (5 b)

The p-nitrobenzoate with m.p. 95-95.5° (from alcohol) did not give a depression of melting point in admixture with the p-nitrobenzoate of D-neocarvomenthol obtained by hydrogenation of carvomenthene oxide. According to the literature [27] the p-nitrobenzoate of L-neocarvomenthol has m.p. 95°.

3. Trans-p-menthane fraction. The hydrocarbon fraction was distilled with sodium. The product did not decolorize bromine in dilute chloroform solution.

B.p.170.5-171.5°(761 mm),59-59.5°(at 16 mm), d_4^{20} 0.7953, n_D^{20} 1.4383, α_D +0.04°, MR_D 46.32 (calc. 46.18).

Literature data [29] for trans-p-menthane: d_4^{20} 0.7964, n_D^{20} 1.4366 ; for cis -p-menthane: d_4^{20} 0.8080, n_D^{20} 1.4414.

Found %: C 85.72, 85.70; H 14.37, 14.54. $C_{10}H_{20}$. Calculated %: C 85.63, H 14.37.

Raman spectrum:

Δν 286 (3), 309 (3), 334 (1), 404 (2), 451 (1), 474 (2), 495 (1), 516 (1), 597 (1), 631 (2), 762 (10), 784 (2), 802 (1), 858 (2), 952 (3), 1027 (3), 1056 (3), 1065 (5), 1096 (1), 1118 (1), 1160—1176 (5), 1201 (1), 1253 (5), 1289 (1), 1306 (2), 1345—1357 (5), 1436 (6), 1459 (8), 2843 (6), 2868 (6), 2907—2925 (4), 2958 (5)

The spectrum closely resembles that of p-menthane prepared by exhaustive hydrogenation of limonene [30].

4. Ketonic fraction (mixture of menthone and carvomenthone). B.p. 88.5-90° (at 13 mm), α_D - 2.84° and α_i / α_j 2.47. From the ketonic fraction was prepared a semicarbazone with m.p. 184-185° which did not give a depression of melting point with the semicarbazone of L-menthone. The Raman spectrum of the ketonic fraction contains, apart from the lines of menthone [31], a series of lines characteristic of carvomenthone [30] (e.g. lines with $\Delta\nu$ 315, 485, 523, 807, 1066, 1266 and 1324 cm^{-1}).

5. High-boiling fraction. The resinous residue with α_D + 24.00° did not distil in an ordinary vacuum; it came over in a 0.5 mm vacuum and gave a nearly vitreous product which was almost odorless; b.p. 170-185° (at 0.5 mm) and α_D + 32.40°. Judging by its ester number (37) it contained about 14% of menthanediol-2,3 monoacetate.

Hydrogenation of carvomenthene oxide. 10 g $Pd(OH)_2$ and 2.5 ml acetic acid were shaken with hydrogen until absorption ceased. Into the flask, cooled with water to +4° was then introduced in a hydrogen stream a mixture of 13.5 g carvomenthene and 10 ml acetic acid which had been made up immediately before the experiment. Further shaking of the flask was effected in a water bath at +4°. Hydrogenation was completed in 1 hour. 1700 ml (calc. 2120 ml) hydrogen was absorbed. 11 portions of carvomenthene oxide in all were hydrogenated in presence of the same batch of catalyst. The mean absorption of hydrogen was 87%.

The products of hydrogenation were worked up as in the case of Δ^3- menthene oxide. A mixture of alcohols and ketones (fraction with b.p. 80-120° at 10 mm) was separated by vacuum distillation from a hydrocarbon fraction (b.p. 50-51° at 10 mm) and from high-boiling products. Sunsequently the ketones were separated from the alcohols by Badoche's method [32] — prolonged shaking of the mixture first with sodium bisulfite solution and then with a solution of semicarbazide hydrochloride and sodium acetate. The alcohols were distilled with steam from the precipitate of semicarbazone (after neutralization of the mixture with sodium bicarbonate); they were then subjected to careful fractionation in vacuum in a column (25 theoretical plates). The following fractions were obtained:

1. D-Neocarvomenthol fraction.

B.p. 101.5-102° (at 17 mm), d_4^{20} 0.9073, n_D^{20} 1.4636, α_D +32.00°, $[\alpha]_D$ + 35.93°, $[\alpha]_j$ +37.61°, $[\alpha]_\nu$ + 42.63°, $[\alpha]_l$ + 71.55°, α_l / α_j 1.90, MR_D 47.49 (calc. 47.60).

Found %: C 76.60, 76.47; H 12.84, 12.89; OH 10.73, 11.13. M 161.8, 160.9. $C_{10}H_{20}O$. Calculated %: C 76.86; H 12.90; OH 10.89. M 156.3

Raman spectrum

Δv: 286 (1), 311 (4), 341 (1), 410 (3), 433 (3), 460 (2), 491 (3), 510 (1), 525 (?), 545 (?), 584 (?), 750 (10), 797 (2), 847 (3), 873 (1), 933 (1), 955 (3), 970 (1), 995 (3m), 1033 (5), 1064 (4), 1096 (3), 1130 (3), 1143 (4), 1174 (1), 1192 (2), 1215 (?), 1253 (5), 1293 (1), 1314 (4), 1335 (1), 1358 (3), 1444—1462 (8), 2859—2874 (5), 2927 (5 b), 2965 (4b).

The 3,5-dinitrobenzoate, prepared from the D-neocarvomenthol fraction, had m.p. 129-129.2° (from alcohol). The p-nitrobenzoate of the same fraction melted at 95-95.5° (from alcohol) and no depression was observed in admixture with the p-nitrobenzoate of the D-neocarvomenthol fraction obtained by hydrogenation of Δ^3-menthene oxide. According to the literature [27] the 3,5-dinitrobenzoate of L-neocarvomenthol melts at 129°; the p-nitrobenzoate at 95°.

2. Fraction containing L-carvomenthol.

B.p. 107.5-108.5° (at 16 mm), d_4^{20} 0.9062, n_D^{20} 1.4640, α_D + 1.48°, $[\alpha]_D$ + 1.63°, MR_D 47.58 (calc. 47.60).

Literature data for D-carvomenthol [27]: b.p. 102° (at 14 mm) d_4^{20} 0.8995, n_D^{20} 1.4617, $[\alpha]_D$ + 26°.

Found %: C 76.92, 76.90; H 12.51, 12.68; OH 11.25. M 158.5, 154.2. $C_{10}H_{20}O$. Calculated %: C 76.86; H 12.90; OH 10.89. M 156.3.

Raman spectrum:

Δv 284 (3), 311 (2), 417 (1), 453 (?), 494 (2), 509 (1), 536 (1), 557 (?), 573 (?), 749 (?), 771 (10), 785 (?), 807 (1), 839 (4), 857 (1), 870 (1), 955 (5), 982 (1), 1005 (2), 1020 (3), 1060 (2), 1078 (?), 1099 (6), 1147 (6), 1177 (6), 1208 (3), 1236 (1), 1265 (3), 1284 (?), 1297 (2), 1349—1363 (4), 1376 (?), 1443—1463 (10), 2852—2878 (5), 2923 (3b), 2955 (3b), 2972 (3 b).

The 3,5-dinitrobenzoate prepared from this fraction had m.p. 106-107° (from alcohol) and $[\alpha]_D$ -48.1° (c 1.9; $CHCl_3$). For the 3,5-dinitrobenzoate of D-carvomenthol the literature [27] reports m.p. 107° and $[\alpha]_D$ +52.80° (c 2.0; $CHCl_3$). The sign of the rotation of the obtained 3,5-dinitrobenzoate indicates that the stereoisomer constituting the main bulk of the fraction in question is levorotatory,* i.e. L-carvomenthol to which was added the D-neocarvomenthol from the preceding fraction. The presence of the latter accounts for the low positive rotation of the present fraction.

3. Menthanol-1 fraction.

B.p. 89-93° (at 11 mm), d_4^{20} 0.9003, n_D^{20} 1.4560, α_D +2.32°, $[\alpha]_D$ +2.58°, MR_D 47.18 (calc. 47.60).

Literature data for menthanol-1 [34]: b.p. 208-209°, d_4^{20} 0.9000, n_D^{20} 1.4619.

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* It is known [33] that the sign of the rotation of the 3,5-dinitrobenzoates of carvomenthols corresponds to the sign of rotation of the carvomenthols themselves.

Found %: OH 10.18, 10.32. M 153.3, 162.2. $C_{10}H_{20}O$. Calculated %: OH 10.89, M 156.3.

Raman spectrum:

Δv 263 (4), 290 (4), 355 (1), 371 (1), 407 (?), 460 (4), 469 (4), 497 (3), 537 (1), 596 (?), 693 (?), 723 (10), 752 (?), 771 (1), 789 (3), 805 (3), 853 (6), 908 (3), 931 (2), 953 (3), 986 (2), 1000 (2), 1032 (7), 1055 (1), 1082 (2), 1100 (2), 1127 (?), 1166—1177 (7), 1250 (1), 1270 (4), 1292 (2), 1335 (2 b), 1361 (3 b), 1432 (4), 1459 (9), 2840 (1), 2870 (9), 2910—2933 (8), 2966 (5 b).

The fraction gave a quantitative reaction with chromic acid for tertiary alcohols [35]; the phenylurethane had m.p. 101-101.5°. For the latter the literature [34] reports m.p. 100-101°.

For the purpose of comparison menthanol-1 was synthesized by hydrogenation of β-terpineol in alcoholic solution in presence of Raney nickel.

B.p. 79-79.5° (at 5 mm), n_D^{20} 1.4606, α_D 0.00°.

Raman spectrum:

Δv 267 (1), 292 (1), 467 (3), 496 (1), 723 (8), 790 (2), 807 (1), 854 (3), 909 (1), 936 (?), 951 (2), 978 (1), 1002 (1), 1032 (4), 1055 (1), 1073 (1), 1101 (2), 1127 (1), 1165—1181 (3), 1273 (3), 1287 (?), 1362 (?), 1458 (7b), 2850 (1 b), 2870 ((b), 2914—2933 (7), 2967 (3 b).

The phenylurethanes of menthanol-1 from β-terpineol and of menthanol-1 from the investigated fraction melted without depression of melting point.

The following products were separated from the mixture of products of hydrogenation of carvomenthene oxide, in addition to the alcoholic fractions:

4. Trans-p-menthane.

B.p. 170-170.5° (at 767 mm), d_4^{20} 0.7961, n_D^{20} 1.4386, α_D 0.00°, MR_D 46.27 (calc. 46.18). The substance did not decolorize bromine in dilute chloroform solution.

Found %: C 85.72, 85.62; H 14.55, 14.47. $C_{10}H_{20}$. Calculated %: C 85.63; H 14.37.

Raman spectrum:

Δv 253 (3), 285 (3), 311 (2), 338 (1), 379 (?), 405 (1), 453 (?), 477 (2), 497 (1), 517 (?), 631 (1), 762 (10), 785 (1), 859 (3), 953 (4), 1028 (3), 1052 (1), 1065 (5), 1096 (?), 1161—1177 (4), 1254 (6), 1305 (1), 1352 (4 b), 1438 (6), 1460 (9), 2850—2870 (8), 2923 (7b), 2958 (7b).

The fraction was identical with the trans-p-menthane fraction isolated from the products of hydrogenation of Δ^2-menthene oxide.

5. D-Carvomenthone. The bisulfite compound obtained during separation of the ketones from the alcohols (see above) was decomposed by heating for 5 minutes with 20% aqueous formaldehyde solution [36]. The separated ketone was extracted with ether, and the extract was washed with ammonia solution (to remove the formaldehyde which had dissolved in the ether) and with water; it was dried with sodium sulfate. A liquid product was obtained after driving off the ether and distilling the residue.

B.p. 110-111° (at 29 mm), d_4^{20} 0.9028, n_D^{20} 1.4536, α_D + 13.92°, $[\alpha]_D$ + 15.42°, $[\alpha]_j$ + 16.61°, $[\alpha]_v$ + 19.85°, $[\alpha]_i$ + 48.91°, $\frac{\alpha_i}{\alpha_D}$ 3.17, MR_D 46.23 (calc. 46.19).

Literature data for L-carvomenthone [32]: b.p. 94-94.5° (at 13 mm), d_4^{20} 0.9033, n_D^{20} 1.4536, α_D − 14.72°, $[\alpha]_D$ − 16°, α_i/α_D 3.03.

Found %: C 77.67, 77.51; H 11.76, 11.89. M 151.3, 151.4. $C_{10}H_{18}O$. Calculated %: C 77.86; H 11.76. M 154.2.

Raman spectrum:

Δv 278 (3), 308 (3), 323 (?), 395 (1), 422 (2), 449 (?), 458 (?), 486 (1), 523 (1), 558 (1), 595 (?), 615 (1), 651 (5 b), 730 (7), 758 (?), 788 (1), 848 (2), 864 (2), 926 (?) 958 (3 b), 988 (1), 1015 (2), 1051 (1), 1090 (2), 1106 (2), 1124 (4), 1148 (2), 1170 (1), 1197 (3), 1219 (1), 1260 (3), 1312—1322 (5), 1359 (3), 1389 (?), 1425 (?), 1450—1462 (10), 1710 (7), 2858—2875 (6), 2936 (5), 2971 (5 b).

The data for the spectrum are very close to those of Bonichon [28] for L-carvomenthone.

The semicarbazone, prepared from the ketone in 99.6% yield, had m.p. 187-188° (depends markedly upon the rate of heating; determined with the capillary in a test tube previously heated to 175°), $[\alpha]_D$ - 32.5° (c 1.2; methanol), $[\alpha]_D$ +24.0° (c 3.8; acetic acid). The semicarbazone underwent mutarotation in acetic acid solution: limiting value $[\alpha]_D$ +50.0°. Literature data for the semicarbazone of L-carvomenthone [37]: temperature of instantaneous melting 205°, $[\alpha]_D$ +32.5° (c 1.2; methanol), $[\alpha]_D$ -26.0° (c 3.8, acetic acid); after mutarotation the limiting value was $[\alpha]_D$ -52.7°.

The 2,4-dinitrophenylhydrazone of the ketone crystallizes in the form of flat needles with m.p. 143.5-144.5° (from alcohol) or in the form of rectangular tablets with m.p. 144-145° (from ethyl acetate). A mixed specimen of the two forms of crystals melted without depression. $[\alpha]_D$ +124° (c 1; ethyl acetate). The 2,4-dinitrophenylhydrazone of L-carvomenthone was prepared for comparison. A mixture of the derivatives of D- and L-carvomenthones showed a slight elevation of melting point. From the 2,4-dinitrophenylhydrazones of both ketones was prepared the 2,4-dinitrophenylhydrazone of inactive carvomenthone by the method of neutralization of rotation (to a solution of the L-derivative was gradually added a small crystal of the D-derivative while checking the value of α_D). The derivative of inactive carvomenthone had m.p. 161-162° (from ethyl acetate) and α_D -0.01°.

6. Isocarvomenthone. The crude semicarbazone, obtained during separation of the ketones from the alcohols, was repeatedly treated with ether in the cold [37]. This brought down the greater part of the semicarbazone; after recrystallization from methanol, needles were obtained which melted without depression in admixture with the semicarbazone of D-carvomenthone prepared from the bisulfite compound. From the ether with which the crude semicarbazone had been treated was also isolated white, compact pellets characteristic of the semicarbazone of isocarvomenthone [37] with m.p. 145-150°. * The amount of isocarvomenthone was not more than 5% of the weight of both ketones.

7. High-boiling products. The resinous residue with α_D +35.68°, non-distillable in the usual vacuum, distilled over at 0.5 mm to give a colorless, very viscous and odorless product with b.p. 126-130° (at 0.5 mm) and α_D^{15} +44.20°.

Found: M 269.3, 271.9; ester number 169.4, 172.2. $C_{10}H_{18}(OH)OCOCH_3$. Calculated M 214.3; ester number 261. $(C_{10}H_{18}O)_2$. Calculated M 308.4; ester number 0. Content of monoacetate of menthanediol-1,2 – 65 %. The unsaponified product is probably a dimer of the oxide (compare the analogous product in Tanaka's experiments[9]).

38 g of high-boiling fraction was saponified with aqueous sodium hydroxide. Extraction of the saponification product with ether gave 19 g of crystalline substance. This crystallized from benzene in the form of scales which deliquesced in the air. After drying in a vacuum-desiccator over P_2O_5 the product had m.p. 88-89° and $[\alpha]_D$ +46.97° (c 10; acetone). Literature data for menthanediol-1,2 [38]: m.p. 88-89° $[\alpha]_D$ + 44° (c 10; acetone).

Found %: OH 19.58, 20.44. $C_{10}H_{18}(OH)_2$. Calculated %: 2OH 19.75.

Reaction of carvomenthene oxide with acetic acid. 8 g of carvomenthene oxide was mixed with 9 ml acetic acid. After 3 hours the mixture was diluted with water and worked up in the same manner as after hydrogenation of the oxide. 5.5 g of the original oxide was obtained (70% of the amount taken), which did not give a precipitate when shaken for many days with sodium bisulfite or semicarbazide (ketone absent). The non-distillable residue (1.5 g; 19%) was saponified with aqueous KOH solution to give menthanediol-1,2 with m.p. 87-88° (from benzene).

Isomerization of carvomenthene oxide under hydrogenation conditions. 1 g of palladium hydroxide was shaken in a hydrogen atmosphere with 15 ml acetic acid for 1 hour. The hydrogen was then purged out with nitrogen, 3 g of carvomenthene oxide was run into the flask, and the mixture was shaken in a nitrogen atmosphere for 4 hours. After the usual working up, vacuum distillation gave 1.45 g (49% of the original weight of material) of product with α_D +21.00°. The semicarbazone was prepared from the latter in 60 % yield; this melted without depression when mixed with the semicarbazone of D-carvomenthone. The resinous residue weighed 1.2 g or 40% of the weight of original oxide.

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* Badoche [37] reports the temperature of instantaneous melting of the semicarbazone of L-isocarvomenthone as 175°. In our (normal) conditions of determination the melting point of this semicarbazone was naturally much lower.

SUMMARY

1. Carvomenthene oxide was prepared and was characterized in detail for the first time.

2. A new catalyst (palladium hydroxide without a support) is proposed for the hydrogenation of terpenic oxides as well as for compounds with a double bond.

3. Oxides of carvomenthene, Δ^2-menthene and Δ^3-menthene were subjected to comparative hydrogenation. A close study was made of the composition of the products of hydrogenation of carvomenthene oxide and Δ^2-menthene oxide in acetic acid. In addition to the normal products of hydrogenation (alcohols) the formation of a saturated hydrocarbon (p-menthane) is observed; the oxides also in part isomerize to ketones, and acetates of the corresponding glycols are formed.

4. Isomerization of carvomenthene oxide to D-carvomenthone during hydrogenation in acetic acid is shown to take place under the action of the palladium catalyst.

5. Raman spectra of carvomenthene oxide, Δ^2- menthene oxide, Δ^3-menthene oxide, D-carvomenthone, D-neocarvomenthol and menthanol-1 were plotted for the first time.

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LINALYL CHLORIDE AND ITS PROPERTIES

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One of us in collaboration with G.B. Troyan [1] treated linalool with PCl_3 in the absence of a solvent and obtained linalyl chloride (α_D -1.6°) whose structure was confirmed by a study of the products of ozonization and analysis of the Raman spectrum. Our objective was the establishment of conditions for preparation of pure linalyl chloride with a higher optical activity and the synthesis of its derivatives.

As in the previous experiments the starting substance was D-linalool. The experimental conditions were slightly modified and led to preparation of a purer linalyl chloride (b.p. 79-80° at 6 mm) possessing a higher rotatory power ($[\alpha]_D$ -4.70°).

Linalyl chloride is an unstable compound; when kept in a sealed tube it darkens and partially decomposes. The Raman spectrum of linalyl chloride contains lines for double bonds with frequencies of $\Delta\nu$ 1671 and 1642 cm^{-1}, corresponding to secondary-tertiary and primary-secondary double bonds. The similar intensities of these lines indicates the high purity of the linalyl chloride since the presence of geranyl chloride would have been reflected by the line with the frequency of $\Delta\nu$ 1671 cm^{-1} being stronger than the line with the frequency of $\Delta\nu$ 1642 cm^{-1}. The nitrosate of linalyl chloride with m.p. 109° contrasted with the nitrosate of geranyl chloride with m.p. 101°. Treatment of linalyl chloride with $AgNO_3$ caused separation of L-linalool (α_D -3.39° whose optical activity is opposite in sign to that of the original D-linalool. We thus have here an example of the Walden inversion: D-linalool is converted into L-linalool via the L-chloride. This transition is accompanied by partial racemization. The purity of the L-linalool formed was checked spectroscopically.

EXPERIMENTAL

Preparation of linalyl chloride. Linalool ex coriander oil had the constants: b.p. 72-73° (4 mm) $[\alpha]_D$ + 14.35°, d_4^{20} 0.8650, n_D^{16} 1.4626. To 100 g linalool in a three-necked flask, equipped with reflux condenser and dropping funnel (calcium chloride tube attached), was added 30 ml freshly distilled PCl_3 while cooling intensively. The temperature of the reaction mixture was about -4°. After completion of reaction, the upper layer was decanted, diluted with an equal volume of ether and neutralized with $CaCO_3$. The ethereal solution was then quickly washed once with water and dried with sodium sulfate. Repeated fractional distillation gave linalyl chloride with the following properties:

B.p. 79-80° (6 mm), $[\alpha]_D - 4.7°$, n_D^{16} 1.4777, d_4^{20} 0.9368.

Found %: Cl 20.18, 20.26. $C_{10}H_{17}Cl$. Calculated %: Cl 20.58.

Raman spectrum of linalyl chloride. The spectrum was plotted with the help of a Zeiss three-prism spectrograph. Slit 0.05 mm; exposure 7 hours; light filter: sodium nitrite solution.

$\Delta\nu$: 635 (2), 995 (0.5), 1253 (1), 1332 (0.5), 1380 (2), 1436 (6), 1456 (5), 1642 (10), 1671 (9), 2855 (1), 2916 (1), 2972 (1).

Preparation of linalyl chloride nitrosate. A mixture of 1 g linalyl chloride, 1 g ethyl nitrite and 1 g glacial acetic acid was cooled to -16°; dropwise addition was then made of 2 ml of a solution of concentrated nitric acid in glacial acetic acid (1:1). After addition of a small quantity of alcohol, the solution was allowed to stand in the cold. The nitrosate came down in the form of white crystals. After many recrystallizations from chloroform and ligroine, linalyl chloride nitrosate had m.p. 109°.

Found %: Cl 13.71, 13.60; N 10.84, 10.90. $C_{10}H_{17}ClN_2O_4$. Calculated %: Cl 13.50; N 10.60.

Preparation of linalool from linalyl chloride. 23.8 g silver nitrate in 66 g aqueous alcohol (64%) was added with cooling to 21.6 g linalyl chloride dissolved in 135 ml alcohol. The precipitated silver chloride was filtered off; the acid filtrate was neutralized with $NaHCO_3$ and the alcohol was removed. The residue was fractionally distilled to give 8.66 g L-linalool with the constants:

B.p. 68-70° (3 mm), $[\alpha]_D^{16}$ −3.93°, d_4^{20} 0.8664, n_D^{16} 1.4630.

Found %: C 77.68, 77.59; H 11.90, 11.82. $C_{10}H_{17}OH$. Calculated %: C 77.92; H 11.69.

Raman spectrum of L-linalool.

Principal lines $\Delta\nu$: 1378 (2), 1442 (4 b), 1645 (5), 1673 (6).

SUMMARY

Linalyl chloride with an optical rotation of $[\alpha]_D$ −4.7° was prepared from D-linalool.

Linalyl chloride gives a nitrosate with m.p. 109°; treatment with silver nitrate gives L-linalool with an optical activity of opposite sign to that of the original D-linalool.

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AUTOXIDATION OF SUBSTITUTED ALKYL HOMOLOGS OF BENZENE

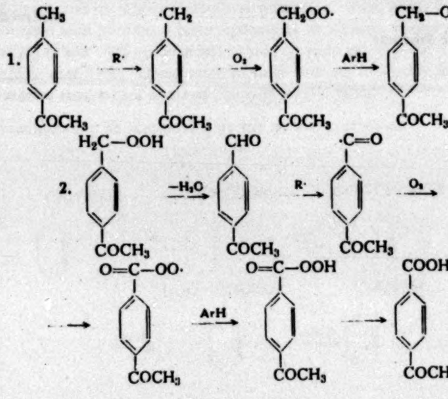
III. PREPARATION OF p-ACETYLBENZOIC ACID

P.G. Sergeev and A.M. Sladkov

In the preceding communication [1] we demonstrated the possibility of autoxidation of p-acetyl-cumene. With the objective of further investigation of the influence of the acetyl group on the oxidizability of the alkyl group in the para-position to the acetyl, we chose p-methylacetophenone as the substance for study.

As we had expected, p-methylacetophenone readily oxidizes at the methyl group linked to the benzene ring. In the present case, however, the initially formed product of autoxidation (p-methylacetophenone hydroperoxide) could not be isolated due to its instability, although the presence of the hydroperoxide could easily be established by iodometric determination. The end product of oxidation was p-acetylbenzoic acid which was obtained in a yield of up to 70% calculated on the p-methylacetophenone consumed. The high yield of p-acetylbenzoic acid (formerly difficultly accessible) and the simplicity of its preparation from the readily accessible p-methylacetophenone renders the method here described a convenient route to this acid for preparative purposes.

Oxidation of p-methylacetophenone may be represented by the scheme:



EXPERIMENTAL

p-Methylacetophenone was obtained by acetylation of toluene with acetic anhydride in presence of anhydrous aluminum chloride. The compound was obtained in 77% yield; b.p. 108-109° (10 mm), n_D^{23} 1.5298. Literature data [2]: b.p. 112.5° (11 mm), n_D^{20} 1.5335.

Autoxidation of p-methylacetophenone. The reaction was carried out at 115-120° in a glass column without packing. Air was added through a glass bubbler at a rate of 0.8 liter/min. Oxidation was performed with 60 g p-methylacetophenone to which 0.01 g nickel benzoate had been added. After 20 hours about 2% hydroperoxide was found in the reaction mass by iodometric determination. At the same time crystals began to separate, and after 10 hours their quantity was so large that the reaction was interrupted. The reaction mass was then filtered from the crystals and again subjected to oxidation. The total oxidation period was 56 hours and the amount of hydroperoxide in the reaction mass had fallen to 1%.

Isolation of p-acetylbenzoic acid. The filtered crystals were dissolved in concentrated aqueous potassium carbonate solution. p-Methylacetophenone was distilled off from the filtrate under reduced pressure (1 mm), the residue was treated with potassium carbonate, and the alkaline extract was added to the main quantity of substance. After extraction with ether, the alkaline solution was acidified with concentrated hydrochloric acid until strongly acid to congo. The precipitated crystals were recrystallized from boiling water. In all 28.5 g acid (m.p. 205-206°) was obtained, or about 70% yield reckoned on the p-methylacetophenone entering into reaction. The literature [3] gives m.p. 208°. The methyl ester, m.p. 93°, was prepared from the acid; a mixture with the authentic substance did not show a depression.

SUMMARY

1. It was shown that autoxidation of p-methylacetophenone gives p-acetylbenzoic acid as the main product.

2. The high yield of p-acetylbenzoic acid (70%) renders the method described for the preparation of this previously difficultly accessible substance of preparative interest.

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THE AUTOXIDATION OF A METHYLENE GROUP ATTACHED TO AN AROMATIC NUCLEUS

PREPARATION OF ESTERS OF PHENYLGLYOXYLIC ACID

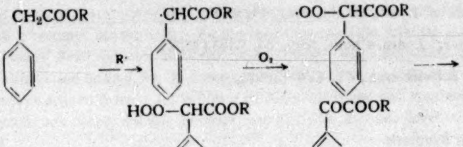
P. G. Sergeev and A. M. Sladkov

It was shown by a number of workers that the phenyl group in alkyl homologs of benzene activates the methylene group in the α-position. This is illustrated, for example, by autoxidation of ethyl benzene [1], n-butylbenzene [2], diphenylmethane [3] and other compounds. We also know that the carbomethoxyl group or the carbethoxyl group increases the reactivity of molecules in radical reactions, for example in the polymerization of the methyl or ethyl esters of acrylic acid [4].

We were interested in the possibility of realizing autoxidations of compounds in which the methylene group subjected to the action of oxygen would be simultaneously under the influence of a phenyl and carbomethoxy or carbethoxyl group. As the simplest representatives of such compounds we selected the methyl and ethyl esters of phenylacetic acid.

It was expected that the methylene group would be extremely reactive. Actually experiments showed that the autoxidation of these esters goes with considerable velocity at the methylene group attached to the benzene nucleus. The end products of the reaction are the methyl and ethyl esters of phenylglyoxylic acid in yields of 86 and 82% respectively. Other methods of synthesis of phenylglyoxylic acid have been described: e.g. oxidation of acetophenone with potassium permanganate in an alkaline medium [5] (yield of phenylglyoxylic acid 70%), of styrene [6] (yield 60%) or mandelic acid [7] (yield of ethyl ester 35-40%), and the hydrolysis of benzonitrile [8] (yield of acid 97%). Comparison of these with our method leads to the conclusion that the latter is the simplest preparative method for esters of phenylglyoxylic acid.

The general reaction may be represented by the following scheme:



EXPERIMENTAL

We prepared the esters from phenylacetic acid and the corresponding alcohols by the method described for methyl phenylacetate [9]. The esters distilled at reduced pressure had the following constants:

Methyl phenylacetate: b.p. 64-65° at 3 mm, n_D^{22} 1.5069. Literature data[10]: b.p. 131-132° at 50 mm, n_D^{16} 1.5091. Ethyl phenylacetate: b.p. 122-123° at 18 mm, n_D^{22} 1.4986. Literature data [11]: b.p. 120-125° at 17-18 mm, $n_D^{18.5}$ 1.49921.

Autoxidation of methyl ester of phenylacetic acid. Oxidation was effected by passing air (0.5 liter per min.) through 42 g of methyl phenylacetate in a glass column fitted with a water trap and a reflux condenser. About 0.1 g cobalt benzoate was added to initiate the reaction and to promote breakdown of the hydroperoxide formed during the process. Oxidation was carried out at 110-115°. After 24 hours 49.8% ketone (determined by oximation) had been formed; after 36 hours the amount was 58.9%; at this stage the oxidation was stopped because no further increase in the size of the aqueous layer in the trap was observed (in all 3.9 ml water was collected). The reaction mixture was distilled at reduced pressure. In this manner about 15 g of unreacted methyl phenylacetate was recovered (b.p. 61-62° at 2 mm), 4.4 g intermediate fraction with b.p. 63-78° at 2 mm, and 22.4 g of a fraction boiling at 78-79° (2 mm), having n_D^{20} 1.5850. The literature [12] gives b.p. 137° (14 mm) for the methyl ester of phenylglyoxylic acid. Yield of methyl ester of phenylglyoxylic acid 85.7% reckoned on the methyl phenylacetate entering into reaction. The compound gave a 2,4-dinitrophenylhydrazone with m.p. 173°.

Found %: N 16.43. $C_{15}H_{12}O_6N_4$. Calculated %: N 16.77.

The ethyl ester of phenylglyoxylic acid was prepared in a similar manner in a yield of 82%. The ester boiled at 117° (5 mm) and had n_D^{22} 1.5198.
Literature data [7]: m.p. 118° (5 mm), n_D^{25} 1.51904.

SUMMARY

Autoxidation of the methyl and ethyl esters of phenylacetic acid led to formation of the esters of phenylglyoxylic acid. The high yields and the accessibility of the starting substances render this reaction a convenient preparative method for esters of phenylglyoxylic acid.

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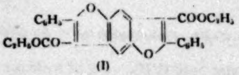
INVESTIGATIONS ON QUINONES

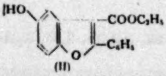
XV. CONDENSATION OF p-BENZOQUINONE WITH BENZOYLACETIC ESTER

A.N. Grinev, Pan Bon Khvar and A.P. Teretyev

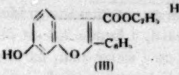
In our researches we have made a detailed study of the reaction of acetoacetic ester with p-benzoquinone and we established that the relative yield of derivatives of benzofuran and benzodifuran depends only on the concentration of quinone in the reaction liquid [1,2]. In the present investigation we showed that benzoylacetic ester reacts with p-benzoquinone in similar fashion: the yield of derivative of benzodifuran(I) increases with increasing concentration of p-benzoquinone in the reaction mixture; if the reaction is performed with very slow addition of quinone to the other reactants, then the sole product is the ethyl ester of 2-phenyl-5-hydroxybenzofuran-3-carboxylic acid (II) in a yield of over 80%. Theoretically, as stated by Graebe [3], this reaction can also lead to formation of the ethyl ester of 2-phenyl-6-hydroxybenzofuran-3-carboxylic acid (III).



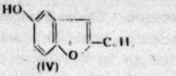
(I)



(II)



(III)



(IV)

The condensation, however, leads only to one derivative of benzofuran(II) whose structure could be confirmed by its transformation into the known 2-phenyl-5-hydroxybenzofuran (IV) [4]. A study was also made of some other reactions of compounds (I) and (II).

EXPERIMENTAL

1. Condensation of benzoylacetic ester with p-benzoquinone. a) 7 g zinc chloride was dissolved in 7 g anhydrous alcohol and 10 g benzoyl acetic ester. To the resultant reaction mixture was added 5.5 g quinone in small portions over a period of 8-10 minutes at 80-90° with stirring. After the whole of the quinone had been added, the mixture was stirred and heated for 30 minutes at 80-90°. The crystals that formed were separated, washed with ether and recrystallized from a 1:1 mixture of dichloroethane and acetone. 4.5 g of (I) was obtained; m.p. 191-192°. The crystals are poorly soluble in ether, alcohol and acetone; soluble in dichloroethane and dioxane.

Found %: C 73.76, 73.92; H 4.96, 5.01. $C_{28}H_{22}O_6$. Calculated %: C 73.98; H 4.88.

The mother liquor was diluted with water and allowed to stand for 72 hours. The resultant semi-crystalline mass was dissolved in ether. The ethereal extract was washed with water and dried with calcium chloride. After removal of the ether, the crystals were collected and washed with a small amount of benzene. 4 g of (II) was obtained in the form of yellowish crystals. Soluble in alcohol and ether, poorly soluble in benzene. M.p. 154-155° (from acetic acid).

Found %: C 72.18, 72.27; H 5.11, 5.20. $C_{17}H_{14}O_4$. Calculated %: C 72.31; H 5.00.

b) The experiment was performed with 38.2 g benzoylacetic ester, 2.8 g zinc chloride, 21.6 g quinone and 28 g anhydrous alcohol. The quinone was added in the course of 45 minutes at the rate of approximately 0.5 g per minute. Reaction temperature 80-90°. After the whole of the quinone had been added, the mixture was heated for 30 minutes at 80-90°. (I) and (II) were separated as in experiment a). Yields: 10 g of (I) and 14 g of (II).

c) The experiment was performed in an extractor without a siphon, using 74 g benzoylacetic ester, 28 g zinc chloride, 21.6 g quinone and 28 g anhydrous alcohol. To the solution of zinc chloride in alcohol in the flask of the extractor was added the benzoylacetic ester and 30 ml absolute ethyl ether. The quinone was placed in the thimble of the extractor. Extraction was effected while the flask of the extractor was heated on an air bath for 26 hours at 110-120° (thermometer in air bath). Crystals separated from the reaction liquid after cooling; they were identified as pure ester (II). M.p. 154-155°. Yield 20 g. Working up of the mother liquor as in a) gave another 27.5 g of (II). Total yield of ester (II) 47.5 g (84.2%).

2. 2-Phenyl-5-hydroxybenzofuran-3-carboxylic acid (V). 2.5 g of (II) in 20 ml alcohol containing 1.2 g NaOH were heated for 40 minutes. Yield 2 g of (V). M.p. 214° (from 50% acetic acid).

Found %: C 71.16, 71.10; H 4.17, 4.34. $C_{15}H_{10}O_4$. Calculated %: C 70.86; H 3.93.

3. 2-Phenyl-5-hydroxybenzofuran (IV). 1 g of acid (V), well stirred with 0.8 g calcium oxide, was heated at 250-300°. Yield 0.45 g of crystals of (IV) with m.p. 186-186.5° (from acetic acid), in agreement with the literature.

4. Ethyl ester of 2-phenyl-5-(p-bromobenzoxy)-benzofuran-3-carboxylic acid (VI). 2.8 g of (II) was dissolved in the cold in 7 ml pyridine. To the solution was added (while cooling with ice) 2.2 g p-bromobenzoyl chloride. The reaction mixture was stood for 4 hours at room temperature and then diluted with water. The crystals were separated, washed with dilute hydrochloric acid and with water and dried. Yield 3 g of (VI). M.p. 134-135° (from alcohol).

Found %: C 62.18, 62.26; H 4.10, 3.93. $C_{24}H_{17}O_5Br$. Calculated %: C 62.07; H 3.69.

5. 2-Phenyl-5-methoxybenzofuran-3-carboxylic acid (VII). 5 g of hydroxy acid (V) was dissolved in 50 ml 2 N sodium hydroxide solution. To the transparent solution was gradually added 2.3 ml dimethyl sulfate with good shaking. After the reaction liquid had cooled, a further 2.2 ml dimethyl sulfate and 4 ml dioxane were added. Heating was carried out for 30 minutes on a water bath, the liquid separating into two layers. 3.2 g sodium hydroxide was added and the stirred mass was heated until the solution was homogeneous. The acid was isolated by the usual procedure. Yield 4.8 g of (VII). M.p. 177° (from acetic acid).

Found %: C 71.86, 71.60; H 4.69, 4.54. $C_{16}H_{12}O_4$. Calculated %: C 71.63; H 4.51.

6. 2-Phenyl-5-methoxybenzofuran. (VIII). The reaction was effected as in exper. 3, using 1 g of acid (VII) and 1 g calcium oxide. Yield of (VIII) 0.4 g. M.p. 124-125° (from acetic acid).

Found %: C 80.36, 80.45; H 5.56, 5.49. $C_{15}H_{12}O_2$. Calculated %: C 80.34, H 5.40.

7. 2,6-Diphenylbenzo-(1,2-b; 4,5-b')-difuran-3,7-dicarboxylic acid (IX). The acid was prepared by hydrolysis of (I) with alcoholic sodium hydroxide. From 1.2 g of (I) was obtained 1 g of acid (IX). Insoluble in organic solvents. Decarboxylation ensued when purification by sublimation was attempted.

8. 2,6-Diphenylbenzo-(1,2-b; 4,5-b')-difuran (X). 1 g of acid (IX) was heated in a sublimation apparatus for $1\frac{1}{2}$ hours at 150-160° 0.7 g of (X) was obtained. White crystals with m.p. above 300°.

Found %: C 84.90, 84.71; H 4.66, 4.58. $C_{22}H_{14}O_2$. Calculated %: C 85.11, H 4.56.

SUMMARY

1. Condensation of benzoylacetic ester with p-benzoquinone proceeds in a manner similar to the reaction of p-benzoquinone with acetoacetic ester.

2. Condensation gives the ethyl ester of 2-phenyl-5-hydroxybenzofuran-3-carboxylic acid. The structure of the latter was confirmed by its transformation into the known 2-phenyl-5-hydroxybenzofuran.

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MERCAPTO ANALOGS OF LYSINE AND SOME OF THEIR DERIVATIVES

I. SYNTHESIS OF ε-MERCAPTO-α-AMINOCAPROIC ACID AND ITS S-ALKYL AND N-SULFANYL DERIVATIVES

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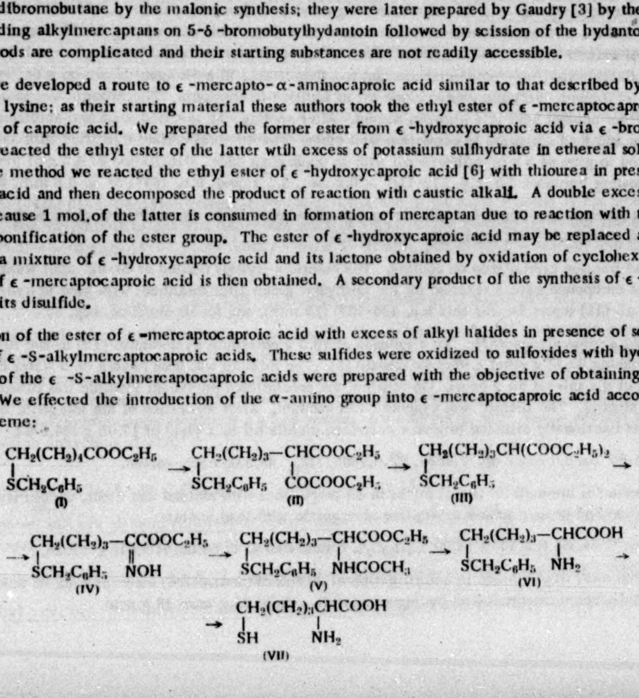
The synthesis of derivatives and analogs of lysine (an essential natural amino acid) and in particular the synthesis of its mercapto analogs is of definite interest in connection with the search for new therapeutic agents on the basis of modern ideas about the importance of the sulfhydryl group in the course of various physiological processes. The group also plays a part in nerve regulation. We also know that some S-alkylmercapto compounds, for example ethylcysteine, possess a relatively high antitubercular activity [1].

Our objective was the synthesis of analogs of lysine in which mercapto groups take the place of α-or ε-amino groups, i.e. the synthesis of α-mercapto-ε-amino and ε-mercapto-α-aminocaproic acids and of α, ε-dimercaptocaproic acid. ε-Mercapto-α-aminocaproic acid has not been described in the literature although its S-methyl and S-benzyl derivatives, as well as the disulfide, have been prepared by Jonson and du Vigneaud [2] from 1,4-dibromobutane by the malonic synthesis; they were later prepared by Gaudry [3] by the action of the corresponding alkylmercaptans on 5-δ-bromobutylhydantoin followed by scission of the hydantoin ring. Both of these methods are complicated and their starting substances are not readily accessible.

We have developed a route to ε-mercapto-α-aminocaproic acid similar to that described by Floyd and Miller [4] for lysine; as their starting material these authors took the ethyl ester of ε-mercaptocaproic acid instead of ethyl ester of caproic acid. We prepared the former ester from ε-hydroxycaproic acid via ε-bromocaproic acid [5]; we reacted the ethyl ester of the latter wtih excess of potassium sulfhydrate in ethereal solution; as an alternative method we reacted the ethyl ester of ε-hydroxycaproic acid [6] with thiourea in presence of hydrobromic acid and then decomposed the product of reaction with caustic alkali. A double excess of thiourea was taken because 1 mol. of the latter is consumed in formation of mercaptan due to reaction with the alcohol formed by saponification of the ester group. The ester of ε-hydroxycaproic acid may be replaced as starting substance by a mixture of ε-hydroxycaproic acid and its lactone obtained by oxidation of cyclohexanone: a lower yield of ε-mercaptocaproic acid is then obtained. A secondary product of the synthesis of ε-mercaptocaproic acid is its disulfide.

Reaction of the ester of ε-mercaptocaproic acid with excess of alkyl halides in presence of sodium alkoxide gave esters of ε-S-alkylmercaptocaproic acids. These sulfides were oxidized to sulfoxides with hydrogen peroxide. Sodium salts of the ε-S-alkylmercaptocaproic acids were prepared with the objective of obtaining soluble derivatives. We effected the introduction of the α-amino group into ε-mercaptocaproic acid according to the following scheme:



$$\underset{\text{(I)}}{\underset{SCH_2C_6H_5}{CH_2}(CH_2)_4COOC_2H_5} \rightarrow \underset{\text{(II)}}{\underset{SCH_2C_6H_5}{CH_2}(CH_2)_3-\underset{COCOOC_2H_5}{CH}COOC_2H_5} \rightarrow \underset{\text{(III)}}{\underset{SCH_2C_6H_5}{CH_2}(CH_2)_3CH(COOC_2H_5)_2} \rightarrow$$

$$\rightarrow \underset{\text{(IV)}}{\underset{SCH_2C_6H_5}{CH_2}(CH_2)_3-\underset{NOH}{\overset{}{C}}COOC_2H_5} \rightarrow \underset{\text{(V)}}{\underset{SCH_2C_6H_5}{CH_2}(CH_2)_3-\underset{NHCOCH_3}{CH}COOC_2H_5} \rightarrow \underset{\text{(VI)}}{\underset{SCH_2C_6H_5}{CH_2}(CH_2)_3-\underset{NH_2}{CH}COOH} \rightarrow$$

$$\rightarrow \underset{\text{(VII)}}{\underset{SH}{CH_2}(CH_2)_3\underset{NH_2}{CH}COOH}$$

Reaction of ethyl-ε-S-benzylmercaptocaproate (I) with diethyl oxalate in presence of sodium ethoxide, while continuously distilling off the alcohol formed, gave the ester of the α-ketoacid (II). This split off carbon monoxide in vacuum at 150-160° in presence of a trace of iron and gave ε-benzylmercaptobutylmalonic ester (III). The monoamide was prepared for characterization. Transformation of the alkylated malonic ester into the oximino ester (IV) was realized by the action of butyl nitrite in a modification of the method of Shivers and Hausen [7]. Reduction with zinc in acetic acid with addition of acetic anhydride gave the acetyl derivative (V) which on saponification gave ε-benzylmercapto-α-aminocaproic acid (VI). Debenzylation with sodium in liquid ammonia led to formation of ε-mercapto-α-aminocaproic acid (VII) which was isolated as the hydrochloride.

We also synthesized some alkyl and sulfanyl derivatives of ε-mercapto-α-amino acids. The synthesis of compounds of this type is confirmation of the presence of free mercapto and amino groups in the products.

Condensation of p-acetylaminobenzene sulfochloride with ε-mercapto-α-aminocaproic acid followed by acidic saponification of the condensation product, under conditions favoring the oxidation of the free mercapto group [8], led to formation of ε-mercapto-α-(p-aminobenzenesulfonamido)-caproic acid. Alkylation of this acid with butyl iodide in an aqueous-alkaline medium by the method of Seebeck [9] gave ε-S-butyl-α-(p-aminobenzene sulfonamido)-caproic acid. We also synthesized the latter by the action of p-acetylaminobenzene sulfochloride on ε-S-butylmercapto-α-aminocaproic acid obtained by alkylation of the original ε-mercapto-α-aminocaproic acid by the method of du Vigneaud [10].

The biological activity of some of the synthesized mercapto compounds was examined in the laboratory of experimental chemotherapy of tumours at the All-Union V. A. Chernov Institute of Pharmaceutical Chemical Research. It was found that ε-ethylmercapto- and ε-mercapto-α-aminocaproic acid possess well-marked antitumour activity both in vitro and in vivo.

EXPERIMENTAL

1. ε-Mercaptocaproic acid. A mixture of 74 g ethyl ε-hydroxycaproate (b.p. 116-125° at 2.5 mm), 66 g thiourea and 315 ml 48% hydrobromic acid was heated on a water bath with stirring for 10 hours. The next day 644 ml of 20% sodium hydroxide solution was added to the reaction mass which was cooled with iced water. The weakly alkaline (to phenolphthalein) solution was then heated in a nitrogen stream on a boiling water bath with stirring for 3 hours. Ethylmercaptan came off in addition to ammonia. The mixture was later heated on a gauze at 120° for another hour in a nitrogen stream. After cooling, the reaction mass was acidified with conc. HCl to congo, and then subjected to extraction with ether. The ethereal extract was dried with sodium sulfate and evaporated to give 54.5 g of yellowish oil with an unpleasant odor. Distillation of 4.5 g of the substance gave the following fractions: 1st, b.p. 112-116° at 0.8 mm, 3.1 g; 2nd, b.p. 163-170° at 0.8 mm, 0.9 g.

The 1st fraction was a colorless oil, giving a positive reaction for the sulfhydryl group with a solution of iodine in lead acetate; it was ε-mercaptocaproic acid.

The 2nd fraction crystallized on cooling. The colorless crystals melted at 80-82° after washing with ligroine. The compound gave a reaction for the sulfhydryl group after treatment with zinc in hydrochloric acid. Ivanovich et al. [11] report for this acid b.p. 155-157° (13 mm), and for its disulfide m.p. 83°.

2. Ethyl ε-mercaptocaproate. To a solution of 16.5 g potassium hydrosulfide [12] in 200 ml alcohol was added with shaking 33.45 g ethyl ε-bromocaproate [5]. The mixture was then heated on a water bath at the boiling point of the solvent for 2 hours. On cooling, the precipitated potassium bromide was filtered off and washed with alcohol. The filtrate was evaporated in vacuum. After separation of the inorganic salt, the compound was fractionally distilled to give a colorless, mobile oil in a yield of 17.05 g (64.5%).

B.p. 84-85° (at 0.7 mm), n_D^{20} 1.4568, d_4^{20} 0.9895, MR_D 48.561; calc. 48.488.

The product is insoluble in water, mixes in all proportions with alcohol and ether, decolorizes 0.1 N solution of iodine and gives a yellow crystalline mercaptide with lead acetate.

Found %: C 54.79; H 9.10; S 18.06. $C_8H_{16}O_2S$. Calculated %: C 54.55; H 9.09; S. 18.18.

The same ester was obtained by esterification of technical (undistilled) mercaptocaproic acid with anhydrous ethyl alcohol saturated wtih hydrogen chloride. Yield 35 g from 48 g acid.

3. Ethyl ε-S-ethylmercaptocaproate. To a solution, prepared from 1.84 g metallic sodium and 60 ml anhydrous alcohol, was added 14.08 g ethyl ε-mercaptocaproate and 13.75 g (10% excess) of ethyl iodide, and the mixture was heated at first at 60-70° for 1 hour and then at the boiling point for 2 hours. Sodium iodide came down and the reaction medium became neutral to litmus. The precipitate was filtered off and washed with alcohol and with ether. The filtrate was evaporated and sodium carbonate solution (50 ml) was added to the residue. The mixture was then extracted with ether. The extract was dried with sodium sulfate and evaporated to give 14.9 g of light-yellow, transparent liquid which was twice distilled; yield 11.8 g.

B.p. 130-134° at 0.8 mm, 150° at 1.2 mm, n_D^{20} 1.4620, d_4^{20} 0.9675, MR_D 58.013; calc. 58.104.

Ethyl ε-S-ethylmercaptocaproate is a transparent, light-yellow, mobile liquid, insoluble in water, readily soluble in ether and alcohol. The compound does not give reactions for the sulfhydryl group and the disulfide bond.

Found % :C 58.77, 58.58; H 9.35; 9.59; S 15.41. $C_{10}H_{20}O_2S$. Calculated %:C 58.82; H 9.80; S 15.68.

4. Ethyl ε-S-benzylmercaptocaproate (I). Prepared in a similar manner to the preceding preparation. Yield 75%.

B.p. 172-173° at 0.6 mm, n_D^{20} 1.5223, d_4^{20} 1.0452, MR_D 77.65; calc. 77.59.

A colorless oil, insoluble in water, miscible in all proportions with alcohol and ether. Does not give reactions for the free mercapto group and for the disulfide bond. The benzyl group is detached by treatment with sodium in liquid ammonia.

Found %: C 67.73; H 8.14; S 11.96. $C_{15}H_{22}O_2$. Calculated %: C 67.67; H 8.27; S 12.03.

To 100 ml liquid ammonia were added 2.66 g of the prepared ester, 0.09 g of sodium and 1 g of ammonium chloride. A violent reaction ensued. Stirring was continued without cooling to evaporate the ammonia, the white residue was dissolved in 25 ml water and the solution was worked up with ether and made acid to congo with hydrochloric acid. Evaporation of the ethereal extract gave ε-mercaptocaproic acid with b.p. 140-145° (7 mm).

5. Ethyl ester of ε-ethylsulfoxidocaproic acid. To a solution of 3.5 g ethyl ε-S-ethylmercaptocaproate in 28 ml glacial acetic acid was gradually added 2.3 g of 27.8% H_2O_2; slight heat was generated. After 3 days standing at room temperature, the reaction mass was evaporated in vacuum and the resultant colorless oil was neutralized with sodium bicarbonate. The residue obtained by removal of the ether from the dried extract was distilied in vacuum. After two distillations the substance boiled at 199-200° at 0.6 mm. Yield 2.1 g (56.5%).

Found %: S 14.58. $C_{10}H_{20}O_3S$. Calculated %: S 14.55.

6. Ethyl ester of ε-benzylsulfoxidocaproic acid. Obtained in the same manner as the preceding compound. Yield 94 %. For the purpose of analysis the compound was recrystallized from 20 times the amount of ligroine. Colorless needles with m.p. 56-57°, very easily soluble in alcohol, poorly soluble in ether and ligroine, insoluble in water.

Found %: C 63.77, 63.64; H 7.57, 7.65. $C_{15}H_{22}O_3S$. Calculated %: C 63.83; H 7.80.

7. Sodium salt of ε-S-ethylmercaptocaproic acid. To a solution prepared from 0.345 g metallic sodium in 15 ml anhydrous alcohol was added 3.1 g ethyl ε-S-ethylmercaptocaproate followed by 55 ml water. The mixture was then heated at the boil for 13 hours until neutral to litmus. The aqueous solution was treated with carbon, evaporated to dryness, white residue washed with anhydrous alcohol and with dry ether. Yield 2.1 g (70.8%). Sodium salt of ε-S-ethylmercaptocaproate is a white powder, not melting at 300°, highly soluble in water and poorly soluble in anhydrous alcohol.

Found %: Na 11.74, 11.80. $C_8H_{15}O_2SNa$. Calculated %: Na 11.62.

8. Sodium salt of ε-S-benzylmercaptocaproic acid. Prepared in a similar manner to the preceding compound. A white powder, very easily soluble in water, poorly soluble in anhydrous alcohol.

Found %: C 59.96; H 6.75; Na 8.87. $C_{13}H_{17}O_2SNa$. Calculated %: C 60.00; H 6.54; Na 8.85.

9. Ethyl ester of δ-S-benzylmercaptobutylmalonic acid (III). To sodium alkoxide, prepared from 30 ml

anhydrous alcohol and 1.15 g sodium were added 7.3 g of diethyl oxalate (the latter previously dried with calcium chloride for 10 days and freshly distilled) and 13.3 g of ethyl ε-S-benzylmercaptocaproate (I). The mixture was heated on a water bath at 50-60° in a low vacuum (90-100 mm) for 2 hours; during this operation ethyl alcohol distilled off. The resultant viscous oil was dissolved in 45 ml water and the solution was washed twice with ether. The aqueous layer was acidified with 10% sulfuric acid until weakly acid to congo, and the oily substance that separated after this treatment was extracted with ether. The ethereal extract was washed with water until neutral to litmus, dried with sodium sulfate and evaporated in vacuum to give 13.52 g of an orange, viscous oil; this was heated with a small amount of iron dust at 150-160° and 30-40 mm for 3 hours and then distilled. B.p. 180-188° (0.6 mm). Yield 10.98 g (65%). Yellow, oily liquid.

Found %: S 59.52. $C_{18}H_{26}O_4S$. Calculated %: S 9.46. *

Monoamide of δ-S-benzylmercaptobutylmalonate. A solution of 0.4 g ethyl δ-S-benzylmercaptobutylmalonate in 20 ml alcohol was saturated with ammonia while being cooled. After standing for 24 hours the solution was evaporated to dryness in vacuum. The amide so obtained was insoluble in ether and poorly soluble in water; m.p. 96-98° after two recrystallizations from alcohol.

Found %: N 4.62; S 10.59. $C_{16}H_{23}O_3NS$. Calculated %: N 4.53; S 10.36.

10. Ethyl ester of α-acetylamino-ε-benzylmercaptocaproic acid (V). To a solution of sodium alkoxide, prepared from 0.91 g sodium and 18 ml anhydrous alcohol, was added 13.35 g ethyl δ-benzylmercaptobutyl malonate. The reaction mass was cooled with water and ice to 2°, and dropwise addition was gradually made at 5-10° of 4.5 g (10% excess) of n-butyl nitrite while stirring. Stirring was continued for 2 ½ hours at room temperature. The excess of alcohol was then distilled off in vacuum at 30-35°. The oily liquid was dissolved in 40 ml water and the solution was twice washed with ether. Acidification of the aqueous layer with hydrochloric acid led to separation of a red oil which was extracted with ether. The ethereal extract was dried with sodium sulfate and evaporated to give 6.99 g (60%) of a dark oil.

To a mixture of 6.92 g of the prepared hydroximino derivative, 15 ml glacial acetic acid and 15 ml acetic anhydride was gradually added 5 g zinc dust (activated with hydrochloric acid) with vigorous stirring. During the operation the temperature rose to 45-50°, after which the mixture was stirred at room temperature for 2 hours. The zinc was thereupon filtered off and washed with glacial acetic acid. The filtrate and wash liquor were evaporated in vacuum. Intensive cooling of the residue led to separation of a white, crystalline substance with m.p. 122-125°. Yield 5.46 g (72%). For the purpose of analysis the substance was twice recrystallized from a mixture of alcohol and ether. Colorless, lustrous needles, m.p. 125-127°, moderately soluble in alcohol and ether, insoluble in water.

Found %: N 4.22; S 9.96. $C_{17}H_{25}O_3NS$. Calculated %: N 4.33; S 9.91.

11. α-Amino-ε-benzylmercaptocaproic acid (VI). A mixture of 4.85 g ethyl α-acetylamino-ε-benzylmercaptocaproate and 35 ml 15% hydrochloric acid was heated on a boiling water bath and stirred for 18 hours. The solution was treated with charcoal, washed with ether and evaporated to dryness in vacuum. Water was added to the residue and evaporated several times. The hydrochloride of α-amino-ε-benzylmercaptocaproic acid obtained in this manner was dissolved in 4.5 g water and treated with charcoal. To the colorless filtrate was added 3 ml pyridine and then 12 ml of hot anhydrous alcohol. The alcoholic solution (strongly cooled) deposited α-amino-ε-benzylmercaptocaproic acid in the course of 24 hours in the form of lustrous needles. Evaporation of the mother liquor to ⅓ of its volume gave a further 0.56 g of the compound. Yield 2.96 g (78%). For the purpose of analysis the substance was recrystallized from alcohol with addition of ether. Lustrous needles with m.p. 238-242° (decomp.). The literature [2] gives m.p. 240-242°. The compound gives a characteristic color with ninhydrin solution when heated and does not give a reaction for the free sulfhydryl group. Moderately soluble in alcohol and water, very sparingly soluble in ether.

Found %: N. 5.36, 5.46; S 13.00 $C_{13}H_{19}O_2NS$. Calculated %: N 5.53; S 12.65.

12. α-Amino-ε-mercaptocaproic acid hydrochloride. To a mixture of 1.45 g α-aminobenzylmercaptocaproic acid and 80 ml liquid ammonia was gradually added 264 mg sodium with stirring. After disappearance of the blue color, the contents of the flask were stirred at room temperature for 3 hours. The white precipitate remaining after evaporation of the ammonia was dissolved in 15 ml water, the solution was made acid to congo with hydrochloric acid, washed with ether and evaporated in vacuum in a nitrogen stream. The residue was

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* As in original — Publisher's note.

twice extracted each time with 5 ml of 10% anhydrous alcoholic solution of hydrogen chloride. Evaporation to dryness in vacuum in a nitrogen stream gave a syrup which crystallized on trituration with ligroine after drying in a vacuum-desiccator over phosphorus pentoxide for 2 days and cooling to -10°. The crystalline mass was twice recrystallized from 20% HCl. Yield 0.75 g of α-amino-ε-mercaptocaproic acid hydrochloride in the form of colorless needles with m.p. 228-234°. The compound gave a blue coloration with ninhydrin, decolorized iodine (in alcohol), and formed a crystalline mercaptide with lead acetate. Readily soluble in alcohol and water; substantially insoluble in common organic solvents.

Found %: N 7.04; S 16.04; Cl 17.86. $C_6H_{13}O_2NS \cdot HCl$. Calculated %: N 7.02; S 16.04; Cl 17.79.

13. α-(p-Aminobenzenesulfonamido)-ε-mercaptocaproic acid hydrochloride. The procedure was similar to that described for the preparation of α-(p-aminobenzenesulfonyl)-D,L-cysteine [5]. Reaction of 0.3 g α-amino-ε-mercaptocaproic acid hydrochloride with 0.42 g p-acetylaminobenzene sulfochloride in presence of 0.1 g sodium hydrosulfite ($Na_2S_2O_4$) gave an oily acetyl derivative which without purification was saponified with 10 ml 15% HCl on a boiling water bath for 1 hour. The acidic solution was cooled to 50° and treated with zinc. It was then evaporated to dryness in vacuum in a nitrogen stream. The residue crystallized when intensively cooled. Two recrystallizations from 20% HCl gave colorless prisms with m.p. 203-208° (decomp.). Yield 0.34 g (64%). Does not give a reaction for the free amino group and forms a crystalline mercaptide with lead acetate.

Found %: N 8.04, 8.11; Cl 9.98, 10.02. $C_{12}H_{18}O_4N_2S_2 \cdot HCl$. Calculated %: N 7.90; Cl 10.01.

14. α-Amino-ε-butylmercaptocaproic acid. α-Amino-ε-benzylmercaptocaproic acid (1.05 g) was treated with metallic sodium (0.3 g) in liquid ammonia (90 ml) and then with butyl iodide (1.65 g) as described for the preparation of α-amino-ε-mercaptocaproic acid. The resultant white precipitate was dissolved in 6 ml water and the aqueous solution washed with ether. The solution was made acid to litmus with acetic acid; a white precipitate with m.p. 248-252° (decomp.) was formed. Yield 0.64 g (70.5 %). For the purpose of analysis the substance was twice recrystallized from hot water to give a white powder with m.p. 250-252° (decomp.) which gave a characteristic reaction with ninhydrin solution.

Found %: N 6.28; S 14.87. $C_{10}H_{21}O_2NS$. Calculated % N 6.39; S 14.61.

15. α-(p-Aminobenzenesulfonamido-ε-butylmercaptocaproic acid hydrochloride. To a solution of 0.4 g α-amino-ε-butylmercaptocaproic acid in 12 ml 0.5 N sodium hydroxide was added 0.51 g p-acetylaminobenzene sulfochloride; the mixture was shaken for 5 hours at room temperature. Non-reacted sulfochloride was filtered off, and the solution was made acid to congo with concentrated hydrochloric acid.

An oil separated. It was freed from mother liquor and saponified (without further purification) by heating with 12 ml HCl (15%) on boiling water for 1 hour. Intensive cooling of the acid solution led to separation of yellowish crystals with m.p. 35-43° (decomp.).

The hydrochloride was recrystallized from 10% HCl (8 ml). A colorless crystalline substance was obtained with m.p. 235-243° (decomp.), readily soluble in benzene and in cold, dilute hydrochloric acid. The reaction for α-amino acid was negative. Yield 0.56 g or 70 % reckoned on the α-aminobutylmercaptocaproic acid.

Found %: N 6.78; Cl 8.71. $C_{16}H_{26}O_4N_2S_2$. Calculated %: N 6.82; S 8.65.

The same compound was obtained by shaking 0.3 g α-(p-aminobenzenesulfonamido)-ε-mercaptocaproic acid with 3.5 ml 1 N NaOH and 0.32 g butyl iodide in 3 ml alcohol for 20 hours at room temperature and in a nitrogen atmosphere.

SUMMARY

· α-Amino-ε-mercaptocaproic acid and its S-butyl-, S-benzyl- and S-sulfanyl derivatives were synthesized.

2. The applicability of the method of preparation of mercapto compounds by the action of thiourea on hydroxy compounds in presence of hydrobromic acid was illustrated by the synthesis of ε-mercaptocaproic acid from ε-hydroxycaproic acid.

3. The preparation of the previously undescribed α-amino-ε-mercaptocaproic acid served as a demonstration of a new variant of the synthesis of ε-mercaptoamino acids from mercapto acids with the help of diethyl oxalate.

4. The ethyl ester ε-mercaptocaproic acid, its alkyl derivatives and their sulfoxides were prepared.

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DISCUSSION

A.K. DMITRIEV'S PAPER ON "CHEMICAL NONEQUIVALENCE OF NASCENT HYDROGEN"

V. S. Kuzub *

On the basis of experiments on the solution of metals in acid in presence of prepared sulfur or of thiocyanate and thiourea, A. K. Dmitriev [1] draws the conclusion that the chemical activity of nascent hydrogen varies and depends on the nature of the metal on whose surface the hydrogen is liberated.

According to P.D. Lukovtsev [2] the release of hydrogen sulfide in Dmitriev's experiments on solution of metals in presence of prepared sulfur is not due to reduction of the sulfur by nascent hydrogen but is probably the result of reduction of oxygenated compounds of sulfur that could be formed or of decomposition of sulfides. Actually, on heating 2 g of sulfur prepared as described by Dmitriev, 20 ml HCl (1:1) and 20 ml H_2O, the presence of hydrogen sulfide can be detected even in the absence of metal. Dmitriev himself mentions the presence of sulfides. According to his results, metals may be arranged in the following order in respect of increasing amount of H_2S evolved during their solution in presence of prepared sulfur: Mg (1), Zn (6), . . . Co (50), Ni (60) (the numbers in brackets are the so-called "iodine values" – the number of milliliters of 0.1 N iodine solution needed for oxidation of the released hydrogen sulfide, proportional to the amount of H_2S).

We see that the first members of this series are metals that dissolve rapidly in acid. The question inevitably arises: is not the amount of hydrogen sulfide evolved proportional to the period taken for solution of the metals, and in turn proportional to the amount of sulfide formed, bearing in mind that 0.2 g Mg and Zn dissolve in minutes and Co and Ni in hours?

As materials for "reduction "Dmitriev took thiourea and potassium thiocyanate as well as sulfur. These compounds form hydrogen sulfide when they react with hydrochloric acid. It is known [3] that heating of potassium thiocyanate with hydrochloric acid takes the course:

$$KCNS + 2HCl + 2H_2O = NH_4Cl + KCl + CO_2 + H_2S \quad (1)$$

The reaction with thiourea is analogous but slower:

$$CS(NH_2)_2 + 2HCl + 2H_2O = 2NH_4Cl + CO_2 + H_2S \quad (2)$$

The table gives the results of parallel experiments with potassium thiocyanate (at 95°, weight of metal 0.2 g, duration 60 minutes) under the conditions of Dmitriev. As we see, the iodine numbers are nearly identical in the majority of cases both in the presence and in the absence of metals.

Concerning dependence of the amount of H_2S on time at constant temperature, we see from Fig. 1 that in the reaction of potassium thiocyanate with hydrochloric acid both with a metal (cobalt was taken as a slowly dissolving metal) and in absence of metal, the amount of H_2S increases with the duration of the experiment; in presence of metal the formation of H_2S is at first more rapid than in the absence of metal; the gases initially evolved on solution of the metal in the acid probably promote mixing. The decrease in amount of free acid

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* Work carried out under the supervision of Prof. A.V. Pamfilov.

gradually slows down the reaction. In the absence of metal the amount of evolved hydrogen sulfide is found to increase with time.

Metal	Iodine number	
	with metal	without metal
Mg	46.9	57.2
Zn	47.8	57.9
Al	56.5	57.3
Cd	57.8	58.2
Sn	58.0	57.6
Co	57.8	58.2
Ni	58.2	58.0

The fall in the content of hydrochloric acid may also account for the fact that the amount of hydrogen sulfide increases on introduction of a small quantity of thiocyanate into the solution, whereas further increase in the amount of KCNS has a progressively smaller effect.

A somewhat different picture is presented by thiourea (Fig. 2). We see that the reaction of thiourea with hydrochloric acid goes slowly. We see from the diagram that curve 1 gradually falls with passage of time after 30 minutes heating. This is because at a temperature close to 100° part of the hydrochloric acid enters the absorbent, where zinc sulfide is formed, together with the hydrogen sulfide, and the longer the duration of heating the greater is the amount of acid entering the absorbent and the greater is the amount of hydrogen sulfide that escapes from the absorbent. It is clear that the same effect will occur even with increase in the concentration of acid. This may account for the fall in the amount of hydrogen sulfide evolved (but not for "the increased rate of evolution of hydrogen " as Dmitriev assumes). The smoother course of curve 2 after 30 minutes heating in comparison with curve 1 is due to formation of a salt by the cobalt on dissolving in the acid, and less acid then enters the absorber.

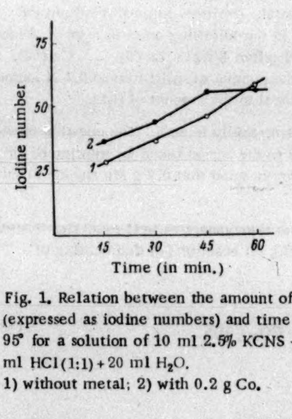

Fig. 1. Relation between the amount of H_2S (expressed as iodine numbers) and time at 95° for a solution of 10 ml 2.5% KCNS + 20 ml HCl (1:1) + 20 ml H_2O.
1) without metal; 2) with 0.2 g Co.

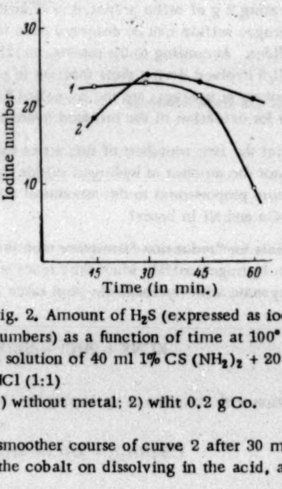

Fig. 2. Amount of H_2S (expressed as iodine numbers) as a function of time at 100° for a solution of 40 ml 1% $CS(NH_2)_2$ + 20 ml HCl (1:1)
1) without metal; 2) wiht 0.2 g Co.

On the basis of Dmitriev's data, L.I. Antropov [4] divided metals into two groups (the first comprising Co and Ni to which the recombination theory of hydrogen overvoltage applies, and the second Mg and Zn for which the theory of retarded discharge is valid). This classification must be regarded as without justification.

SUMMARY

1. The hydrogen sulfide evolved when metals dissolve in acid in presence of prepared sulfur is probably not formed by reduction of the sulfur by nascent hydrogen, as assumed by A.K. Dmitriev, but as the result of decomposition of sulfides.

2. Reaction of potassium thiocyanate or thiourea with hydrochloric acid leads to release of hydrogen sulfide in quantity proportional to the duration of the reaction irrespective of the nature of the metal.

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LETTERS TO THE EDITORS

I

In no. 6 of Journal of General Chemistry for 1956 appeared a letter from L. N. Mushkalo in which he states that the 4-methyl-2-dimethylaminoethylthiazole described in my paper on "The Mannich reaction in the thiazole series" [J. Gen. Chem., 26, 491 (1956)] was prepared by him in 1949 (Ukr. Chem. J., 15, 467 (1949)], and he reproaches us for not having cited his work. We were unaware of this work because it had not been reported in the abstract journals. The following comment may now be made.

Reaction between 2,4-dimethylthiazole, paraformaldehyde and dimethylamine gave us two substances: 4-methyl-2-β-dimethylaminoethylthiazole (picrate with m.p. 105-106.5°) and 4-methyl-2-di-(dimethylaminomethyl)-methylthiazole (picrate m.p. 150-151.5°, methiodide m.p. 208-209°). (The compounds were analyzed for C, H and N.) From the same reactants L.N. Mushkalo obtained only one substance; the constants of its derivatives (picrate m.p. 166-168°, methiodide m.p. 196-197°) indicate that it differs from both of our compounds. Since L.N. Mushkalo only determined the nitrogen content of his compound, it is difficult to say on the basis of the data that the compound is (as claimed by Mushkalo) 4-methyl-2-dimethylaminoethylthiazole.

B. M. Mikhailov
I.K. Platova

II

In the paper by P. Pfeiffer and E. Enders on "New polymethine dyes" [Chem. Ber., 84, 313 (1951)] the authors describe the synthesis of new polymethine dyes including those formed by opening of the pyridine ring under the action of compounds containing active methylene groups. The following conclusions may be drawn from the data in the paper: 1) The authors consider that no work had been published (prior to 1950) on the scission of the pyridine ring by acidic compounds (". . . it had been impossible to split the pyridine ring without using compounds of a basic character . . . "); 2) the scission of the pyridine ring in pyridinium salts by compounds containing an active methylene group was discovered by these authors in 1950.

In this connection it is necessary to point out that the Patent Division of the State Committee of the Council of Ministers of the USSR for the establishment of advanced technology in the national economy granted me Author's Certificate No. 12098, with priority from June 26, 1945, in which was described the preparation of polymethine dyes by scission of the pyridine ring by compounds of a non-basic character – phloroglucinol and resorcinol. On the basis of the experimental work that had been undertaken, it was concluded that the mechanism of scission of pyridinium salts when using phloroglucinol and resorcinol is bound up with the phenomenon of phototropy in presence of active methylene groups. In the light of these facts it is not "surprising" (as the authors put it) that a polymethine dye should be formed from the lactone of o-hydroxyphenylacetic acid and p-nitrobenzoyl chloride in a medium of pyridine.

N. E. Podkletnov

III

We earnestly request the insertion of a list of errors, caused by our oversight, in the paper on "Investigations of the equilibrium in the system cuprammonium sulfate-zinc ammonium sulfate-water at 20° with the help of the radioactive isotopes Zn^{65} and Cu^{64}" [J. Gen. Chem., 26, 1821 (1956)]. On p. 1823 in Table 2 in column 6, the first two entries should read 213 and 211 (imp.min.) instead of 113 and 111. On p. 1823 in the formula for the magnitude of a_{cr} the denominator should be $c_{cr} - c_{M.r.}$ instead of $c_{cr.} \cdot c_{M.r.}$ On p. 1824 in Table 3, column 1, the first entry should be 67.8 (imp. min.) instead of 61.9; in column 7 the first, second and fourth entries should be 73.0, 71.8 and 191 (imp. min) instead of 65.9, 70.4 and 111; in column 8 the first entry should be 0.42 instead of 0.38.

G.I. Gorshtein
N.I. Silantyeva